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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 2 MARCH, 1935 Number 2

Aircraft Engine Performance with 100 Octane Fuel

Presented at the Power Plants and Fuels Session, Third Annual Meeting, I. Ae. S.

F. D. KLEIN, *Air Corps, Wright Field*

INTRODUCTION

WITH the present use of Air Corps Specification No. Y–3557–G fuel having an anti-knock value of 92 Octane by the method of test covered in Air Corps Specification No. 3566, in engines designed for maximum performance on such fuel, an increase of about 33⅓ percent in power output per unit weight has been obtained over that possible with earlier type engines which operated with about 50 Octane Number fuel prior to 1928. Until recently, anti-knock value higher than the present Air Corps standard did not appear to be practicable for service use because of prohibitive cost, limited availability and necessarily high lead content resulting in excessive corrosion difficulties.

Developments of the fuel industry made possible early in 1934 the production of commercial iso-octane on a large scale at a cost sufficiently low to make the outlook for higher anti-knock fuels appear decidedly promising. The Air Corps, anticipating a need for 100 Octane fuel, prepared an experimental specification, No. X–3575, for such fuel on February 1, 1934. This specification has now been distributed to leading fuel refiners for comments preliminary to adoption of the fuel as standard. In addition to increase in anti-knock value, the maximum allowable lead content has been reduced in this specification to 3 ml. per gallon, as compared with the 6 ml. per gallon allowed in Air Corps Specification No. Y–3557–G. Fuel furnished on current procurement to Specification Y–3557–G has in general contained from 3.5 to 5.5 ml. of lead per gallon, averaging about 4.0 ml. An adequate potential supply of 100 Octane fuel appears to be available with a lead content of close to, but not greater than 3.0 ml. per gallon. Thus, the higher anti-knock value will be accompanied by a reduction in engine corrosion.

One thousand gallons of commercial iso-octane (2,2,4 trimethyl pentane) was procured in May, 1934 to be blended with good quality aviation gasoline to make 2000 gallons of 100 Octane fuel containing 3.0 ml. of tetraethyl lead per gallon, sufficient for experimental multi-cylinder engine tests to determine the increase in power output possible with such fuel.

DESCRIPTION OF TESTS

As a result of considerable preliminary determinations of physical properties and anti-knock value of various fuels available, four were selected as being of the greatest interest for comparison with 92 Octane Specification Y–3557–G fuel in multi-cylinder aircraft engines. Each of these four fuels had an anti-knock value of 100 Octane by the Air Corps method of test, and each conformed closely with all other requirements of Specification X–3575 except in tetraethyl lead content. A brief description of the four fuels is given in Table I.

TABLE I.

Power Plant Fuel No.	Composition of Base Fuel	PbEt4 per Gal.
530	50% iso-octane+50% aviation gasoline	3.0 ml.
531	50% iso-octane+50% aviation gasoline	6.0 ml.
532	Standard Reference Fuel C-6	8.5 ml.
533	37.5% iso-octane+37.5% high anti-knock fuel about half composed of aromatics+25% iso-pentane	1.0 ml.

Fuel No. 531 differed from Fuel No. 530 only in lead content, as shown, and was included in the tests to determine whether any increase in power output would be obtained due to the additional lead, the knock tests showing no appreciable difference in anti-knock value apparently due to the poor lead susceptibility of 100 Octane fuels. In Fuel No. 533, the iso-octane was used to increase the anti-knock value and lead susceptibility of the aromatic fuel, and the iso-pentane was added to reduce the A.S.T.M. 10% evaporated point so that it would conform to the requirements of Specification X–3575.

A brief description of the two engines used is given in Table II.

TABLE II.

Commercial Name	Compression Ratio	Impeller Gear Ratio	Impeller Diameter	R.P.M. Used During Tests
Wasp	6 : 1	14 : 1	6¾″	2200
Cyclone	6.4 : 1	10 : 1	11″	1950

The following tests were conducted with the Wasp engine:

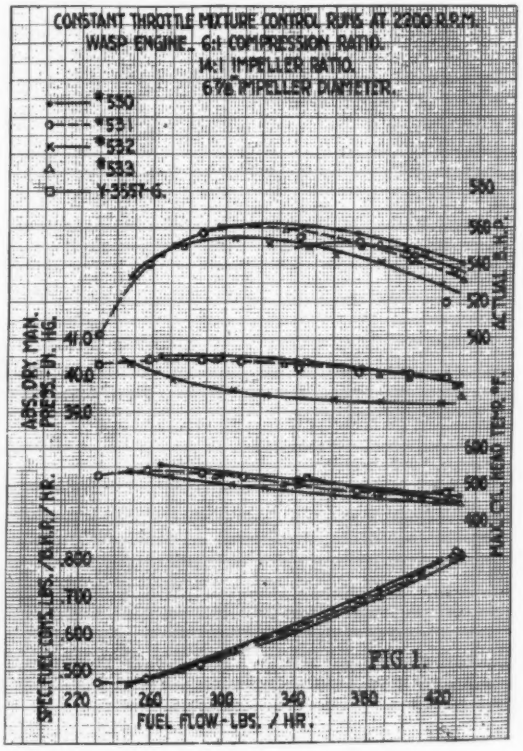
(1) Constant throttle mixture control runs with each of the four 100 Octane fuels and the Y–3557–G fuel.

(2) Constant specific fuel consumption, variable throttle runs with each of these five fuels at specific fuel consumption of approximately .55 pound per brake horsepower per hour.

(3) Constant specific fuel consumption, variable throttle runs with Fuels Nos. 530 and 531 and Specification Y–3557–G fuel, at specific fuel consumptions of approximately .62 and .72 pound per brake horsepower per hour.

On these variable throttle runs, the throttle was opened progressively until the maximum allowable cylinder temperature of 550°F. was reached.

With the Cyclone engine, constant specific fuel consumption, variable throttle runs were made with each of the five fuels. A reduced air blast was used so that detonation more quickly would be indicated by increase in cylinder temperature. Runs were made at specific fuel consumptions of approximately .60 and .80 pound per brake horsepower per hour. The throttle was opened progressively in each case until the engine suddenly became very rough and cut out. This occurred before excessive cylinder temperatures were reached. The exhausts indicated detonation just before cutting out occurred, but no rapid increase in cylinder temperature was apparent except in the case of the Specification Y–3557–G fuel, with which it appeared that excessive temperature would soon be reached. It is possible that the irregular operation was due to preignition or to failure of the spark plugs to fire consistently under the high compression pressure existing.



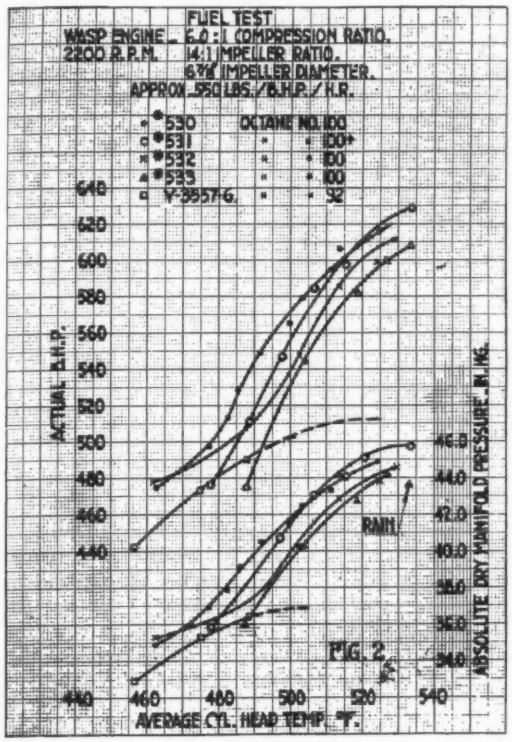


FIG. 2.

Results

Fig. 1 shows the results of the mixture control run in the Wasp engine. Actual brake horsepower, absolute dry manifold pressure, maximum cylinder head temperature and specific fuel consumption are plotted against fuel flow. The curves for Fuel No. 532 are apparently in error, as there is no satisfactory explanation for the variation in manifold pressure, and later tests showed little difference between this and other 100 Octane fuels. Neglecting this fuel, the other three 100 Octane fuels appear equal, and the Specification Y–3557–G fuel appears inferior in view of the excessive cylinder temperature experienced.

Fig. 2 shows the results of the variable throttle run in the Wasp engine at approximately .55 pound per brake horsepower per hour specific fuel consumption. Actual brake horsepower and absolute dry manifold pressure are plotted against average cylinder head temperature. Fuels Nos. 530 and 531 appear slightly superior to Nos. 532 and 533, and show 620 hp. as compared with 510 hp. for Specification Y–3557–G fuel, a 21.6 per cent increase.

Fig. 3 shows the composite results of the variable throttle runs in the Wasp engine with Fuels Nos. 530 and 531 and Specification Y–3557–G fuel. Actual brake horsepower is plotted against average cylinder head temperature. The solid curve was obtained at a specific fuel consumption of approximately .55 pound per brake horsepower per hour; the dotted curve approximately .62 pound per brake horsepower per hour; and the broken curve approximately .72 pound per brake horsepower per hour. It is seen that at .62 specific fuel consumption, 650 hp. is obtained with the 100 Octane fuel as compared with 540 hp. with the Specification Y–3557–G fuel, a 20 percent increase. At .72 specific fuel consumption, 650 hp. is obtained with the 100 Octane fuel as compared with 580 hp. with the Specification Y–3557–G fuel, a 12 percent increase.

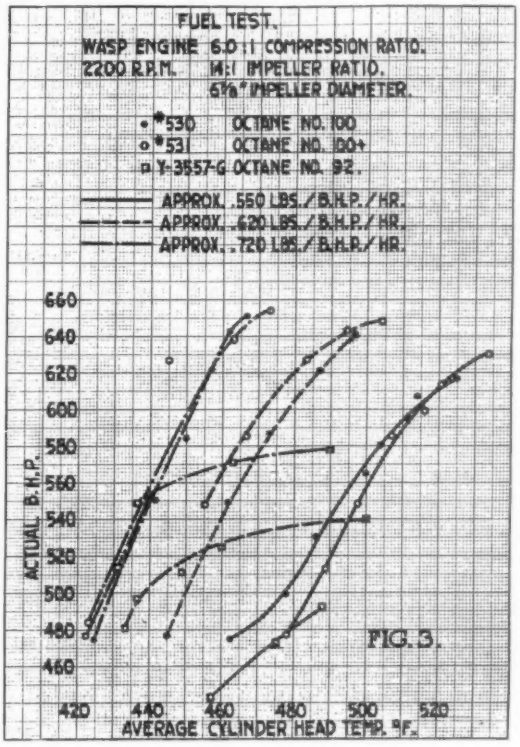


FIG. 3.

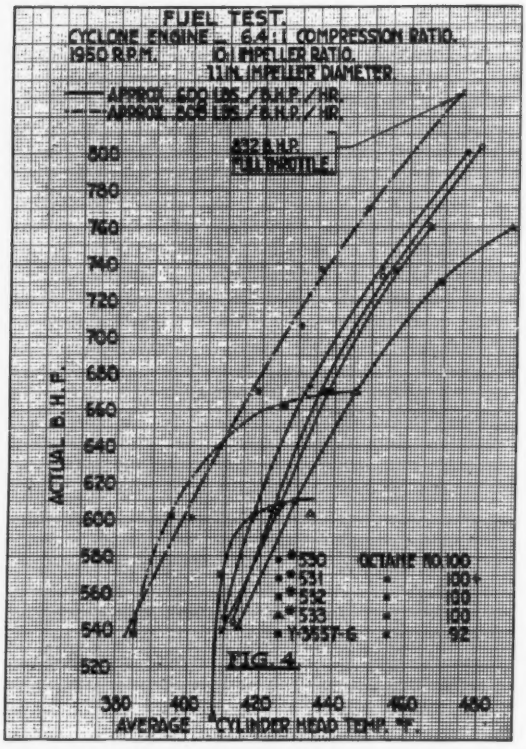


Fig. 4 shows the results of the variable throttle run in the Cyclone engine, using all of the five fuels. Actual brake horsepower is plotted against average cylinder head temperature. The solid curve was obtained at a specific fuel consumption of approximately .60 pound per brake horsepower per hour. In this engine Fuel No. 533 appears to be about 2 Octane Numbers poorer than the other 100 Octane fuels. At a specific fuel consumption of approximately .60 pound per brake horsepower per hour, it is seen that Fuels Nos. 530 and 531 show 800 hp. as compared with 610 hp. for the Specification Y–3557–G fuel, a 31 percent increase. At a specific fuel consumption of approximately .80 pound per brake horsepower per hour, Fuel No. 530 shows 830 hp. as compared with 670 hp. for the Specification Y–3557–G fuel, a 24 percent increase.

The greater increase in power output obtained in the case of the Cyclone engine, as compared with the Wasp, was due to the special impeller used to give extremely high degree of supercharge, in order to show, as clearly as possible at this time, the value of 100 Octane fuel in engines having high enough output available to take sufficient advantage of such fuel. With engines designed specifically for operation on 100 Octane fuel, still greater gain in performance should be obtained, particularly at high altitudes. Anti-knock value has been found to decrease at the rate of one Octane Number per 11–18°F. increase in mixture temperature, so that highly-supercharged engines, to take full advantage of the high anti-knock value of the fuel, would probably require intercoolers for maximum performance on take-off and at low altitude, regardless of the anti-knock value of the fuel used.

The multi-cylinder engine tests show close agreement of the 100 Octane fuels with their rating in the CFR engine under the Air Corps method of test, with the one exception of Fuel No. 533 which in the Cyclone engine appears to be about two Octane Numbers lower than indicated by the CFR knock test. It is interesting to note that Fuel No. 531, although it contains more lead than Fuel No. 530, is rated the same both by the multi-cylinder engines and the CFR engine. In this connection, pure iso-octane upon the addition of 3 ml. of lead per gallon has been found to increase only the equivalent of three Octane Numbers in anti-knock value, when tested in accordance with the Air Corps method of knock test.

Flight Tests

Several pursuit planes undergoing performance tests at Wright Field recently have encountered difficulties, the engines overheating when operated on Specification Y–3557–G fuel. In one case it was essential to determine high speed on the speed course; full throttle operation was made possible by the use of 100 Octane fuel. In another case overheating was experienced in checking the rate of climb; by substituting 100 Octane fuel, the cylinder head temperatures dropped about 30°C., making it possible to complete the test without exceeding the maximum allowable cylinder temperature.

In the Mitchel Trophy Race, held at Selfridge Field, Michigan in November, 1934, ten P-26A's

competed over a closed five mile course, the race being four laps. These airplanes were equipped with high-output engines which could not be opened fully near the ground. To make possible an increase in the power output, and thereby raise the speed of the race, 100 Octane fuel was used. This permitted the airplanes to operate with a reasonable margin of safety at considerably higher speed than was possible on the original performance test on a straight course at sea level using Specification Y–3557–G fuel, and no detonation was evident to the pilots. The race was won at 216.8 m.p.h. This speed is low compared with that of racing planes, because this race is limited to standard service type pursuit planes. In a different race on the same day, for the Junior Birdmen's Trophy, a similar P-26A averaged considerably higher speed over a straight mile course.

Conclusions

The marked increase of 15–30 percent in power output possible with 100 Octane fuel over that obtainable with fuel of 92 Octane Number anti-knock value by the Air Corps method of knock test clearly demonstrates not only the advantages of this fuel, but more important, the extreme desirability from a military standpoint of adopting such fuel as a means of greatly increasing engine performance with relatively little increase in weight, provided that engines are designed to take full advantage of the higher anti-knock value fuels.

Acknowledgments

The author desires to give credit to S. D. Heron, formerly of the Power Plant Branch, Materiel Division, whose foresight was largely responsible for the interest of the Air Corps in 100 Octane fuel; to E. R. Irwin of the Material Branch, who conducted laboratory tests of various fuels aiding in the choice of the fuels to be tested; to W. R. Hopkins of the Power Plant Branch, who conducted the multi-cylinder engine tests of the 100 Octane fuel, and from whose report the greater part of the data given herein were taken; to the many other engineers of the Materiel Division who have made this paper possible through their assistance in planning tests and offering constructive criticisms; and to the officials of the Air Corps who have authorized the presentation of this paper.

Note: It is regretted that no bibliography or references can be given, as the paper is based entirely on tests conducted by the Air Corps, covered by Materiel Division reports not available for general distribution.

Passenger Comfort in Air Transportation

Presented at the Air Transport Session, Third Annual Meeting, I. Ae. S.

P. R. BASSETT, *Sperry Gyroscope Company*

COMFORT is an inward feeling of well being produced by receiving normal stimuli from outside. Abnormal stimuli received through any of our senses cause discomfort. To determine the range of normal stimuli takes considerable study and accumulation of data, since individuals vary in their response because of their physical condition and accommodation caused by experience. It is possible, however, to obtain mean figures for almost all types of stimuli to which we are subjected. For example, it is quite well determined that the comfort temperature for a room is 70°F.±5°F.

Transportation, however, subjects us to a much greater range of magnitude of stimuli, and even brings many entirely new stimuli. It is very difficult for us to adapt ourselves to many of the combinations of stimuli. Such failure to accommodate brings about discomfort and this discomfort may even result in what we could term "transportation sickness." Car sickness, sea sickness, air sickness are all very similar in their symptoms and effects. The general subject of comfort in transportation, however, must include a greater range of conditions than that producing sickness, since there are at least ten people who are uncomfortable for every one who may be actually sick.

It is quite possible, in plotting any stimulus, to divide it into zones of comfort, discomfort and physically unbearable. In this study, the whole subject of passenger comfort has been approached by separating all of the contributing stimuli into comfort, discomfort and unbearable zones. The main stimuli which go to make up a passenger's environment are as follows:

Change of angle or attitude of the carrier; Accelerations of the carrier; Noise level; Vibration; Amount of ventilation; Smell; Heat; Cold; Altitude, and Rate of descent.

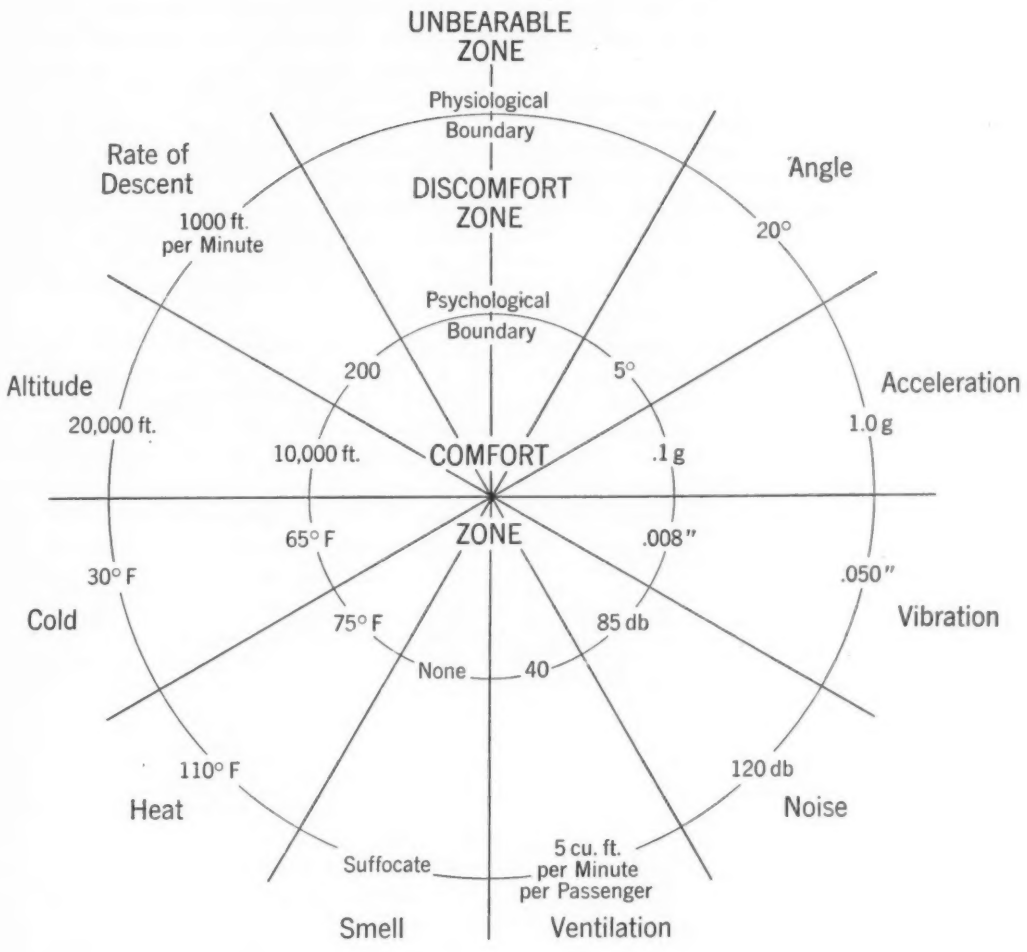
Recent studies of these factors have made it possible to assign approximate magnitudes to the division points between comfort, discomfort and unbearable. The boundary between comfort and discomfort may be termed "the psychological boundary," since the discomfort is largely in the mind and very little of it is actually physical. As the magnitude increases, however, the physical discomfort increases in proportion until, when we reach the second boundary between discomfort and unbearable, this may be termed "the physiological boundary," beyond which the human body cannot function continuously. By plotting the above list of stimuli radially, we can make a polar chart of the three zones. Referring to this chart, the first section is angle of attitude. Here the best information can be obtained from a study of ships at sea. When a ship rolls 5 deg. or less, the passengers (excluding pathological cases) remain comfortable. Beyond 5 deg., the actual physical discomfort increases rapidly until, at 20 deg. roll, it is safe to say everyone is uncomfortable, and all those who are going to be seasick are already so.

The second section is acceleration. Aboard ship, acceleration contributes to seasickness mainly through pitching. In an airplane, acceleration is one of the worst stimuli when the air is turbulent or "bumpy." Studies made by the author both on ships and in airplanes show that the comfort zone of acceleration must lie between 0 and .1 g. The discomfort zone lies between .1 and 1.0 g. It is very interesting to note that this range is approximately identical for both ships at sea and airplanes. The main reason that this is not more evident to the ordinary observer is that, in ships, the major stimulus is angular change, whereas, in airplanes, the major stimulus is vertical acceleration.

The next sector is noise. Here we have found, as a result of three years' experience on measuring airplane noise and soundproofing of passenger planes, that the comfort level lies approximately under 85 decibels. The discomfort range is from 85 decibels to 120, and the unbearable zone is greater than 120 decibels.[1]

[1] The noise level figures here quoted are on the scale having as a base 10^{-16} watts.

PASSENGER COMFORT CHART



Vibration is an important stimulus where the passenger is continuously in contact with vibrating parts. It is not difficult to cushion the seats so that very little vibration reaches the passenger through the seat, but it is equally important to prevent vibration of chair arms, floor, foot rest, head rest and window sills. Vibrations of more than .008 of an inch cause a passenger to keep his muscles tense, consequently making it impossible to relax. Such a condition is contributory to a general feeling of discomfort and possibly sickness by causing the other stimuli to be exaggerated under the nervous tension of vibration.

Ventilation. It has been found that more cubic feet of air per passenger is needed in airplanes than in other forms of transportation. Studies of passenger comfort with ventilation capacities of different volumes have shown that a minimum of 30 cubic feet of air per minute per passenger is necessary.

The next sector, though difficult to put in terms of figures, is too important to omit. This is the stimulus of smell. In some of the early

attempts at cabin heating, air was heated by the exhaust manifold and then taken into the cabin. Such air frequently smelled scorched or occasionally smelled of oil. The condition was found unbearable. Even a trace of smell causes extreme discomfort in the air.

Heat and Cold. Temperature control is divided into two sectors, heat and cold, since it forms two types of discomfort. The comfortable mean between too hot and too cold is not wide. 60°F. may be considered the minimum and 75°F. the maximum. It is, however, desirable to control the temperature in airplane cabins even more closely 71°F.±2°F. should be required.

Air transportation brings in another stimulus which does not come in other forms of transportation, and that is atmospheric pressure. It is only recently that this has become an important passenger factor. With airplanes flying at altitudes of over 10,000 feet, a new form of discomfort is introduced. This discomfort zone starts at approximately 10,000 feet. It is due mainly to lack of oxygen. It leads to a different type of sickness from that which has been termed "transportation sickness." It is similar to "mountain sickness." Although oxygen has been used in attempts to alleviate this high altitude trouble, the ultimate solution must be supercharging of the cabin to a pressure equivalent to 10,000 feet.

Altitude. The last sector; rate of change of pressure, is another comparatively new condition which can cause such extreme discomfort that air transport operators must recognize the limitations of the comfort zone. Experience has already shown that, in coming down from high altitudes, passenger comfort can only be maintained if the rate of descent is 200 feet per minute or less.

There is one other element which cannot be plotted on this chart, but which, in air transportation, is so important that it must be mentioned. This is the element of fear. It is a recognized fact that air sickness runs much higher among new air passengers than among experienced ones. Some air transport folks, who have had charge of passengers in flight, state that fear is probably the greatest contributing cause of air sickness. This probably was so during the earlier years of air transportation. Fear, however, is rapidly diminishing for two reasons; first, air transportation is becoming commonplace, and second, the passenger accommodations are so much improved that fear alone cannot cause sickness. In the past, fear has merely built up the nervous tension so that the other stimuli, such as noise and acceleration, caused air sickness.

The main point which it is desired to bring out in this chart is the fact that whereas pilots can stand the stimuli all the way out to the physiological zone without complaining, the passenger starts to complain at the beginning of the psychological zone. It must be realized that in order to serve the passenger, all stimuli must be kept within the comfort zone. Passenger air transportation is so new that it only seems yesterday where passengers were flown in planes in which the pilots and passengers were submitted to the same conditions. It was considered that if the pilot could take it so could the passengers. It was just the penalty in discomfort which had to be suffered for the added speed. We now know that this is entirely a fallacy. Within the last year or so, it has been proven that practically all of these conditions can be reduced to a point below the psychological boundary so that the passenger will have no complaint. More than that, we can now say that the comfort of air transportation can actually be brought to a point where it is greater than other forms of transportation. We can confidently look forward to the transport airplane of the immediate future being not only the fastest, but also the most comfortable form of transportation.

Measurement of Altitude in Record Flights

Presented at the Instruments Session, Third Annual Meeting, I. Ae. S.

W. G. BROMBACHER, *National Bureau of Standards*

IN making an international record for altitude in airplane and balloon flights it is now necessary to secure in flight only a record of the air pressure against time. The lowest pressure attained is converted to altitude by means of the altitude-pressure relation of the Fédération Aéronautique Internationale (F.A.I.) standard atmosphere, which has been adopted internationally for such use. This relation is as follows:

$$Z=(K_1+K_2P+K_3P^2)\log\frac{760}{P},$$

where, in metric units, $K_1=15320$; $K_2=8.65$; and $K_3=0.0055$. Altitudes in this atmosphere for various pressures are given in Table I together

TABLE I. *Standard atmosphere altitude-pressure table.*

Pressure mm. Hg.	F.A.I. Feet	U.S. Feet	Difference Feet
760	0	0	0
400	16371	16713	342
300	23071	23566	495
200	32014	32610	596
100	46614	47156	542
90	48802	49362	560
50	61027	61669	642
40	65689	66341	652
30	71726	72365	639
20	—	80854	—

with corresponding altitudes in the United States standard atmosphere.

For high altitude flights a double traverse barograph is generally used in this country to secure a record of air pressure against time. The trace is made by a stylus operating on a smoked chart of paper or aluminum sheet. Many of the barographs used contain a bimetallic element for recording the instrument temperature in order to afford data for eliminating the effect of temperature upon the readings of the instrument.

In this country the barograph is tested at the National Bureau of Standards. The test consists essentially in subjecting the barograph to a flight history test, during which the conditions of the flight as to instrument temperature and rate of change of air pressure are reproduced. The lowest pressure indicated by the barograph is measured by a mercurial barometer of the altitude type, or, if beyond the range of the barometer, by means of a mercurial manometer and cathetometer. The air pressure indicated by the barograph at the time of take-off is also determined and when such data are available, is compared with the air pressure at the ground level measured by mercurial barometer by the Weather Bureau. This furnishes a valuable check upon the trustworthiness of the barograph.

The F.A.I. in principle has recently adopted for comparison the actual altitude as determined by the barometric formula. The details of making the necessary flight and ground measurements and testing of instruments have been agreed upon and the new method is to go into effect on July 1, 1935. The following observations will have to be obtained: (a) air pressure at highest altitude, (b) air pressure at ground level, (c) air temperature from ground to highest altitude and (d) the elevation above sea level of the point at which the air pressure at the ground is measured. Data (a) and (c) must be recorded in flight, for which the instruments used in aerological flights are now commonly available.

The most important feature of this change is the abandonment of a standard atmosphere for comparing the highest altitudes attained by aircraft. It is commonly accepted that a comparison of the performance of airplanes depends on the air pressure and air temperature at the flight level. These two quantities are used to obtain the performance at an altitude in a standard atmosphere. Various methods of reduction are used upon which there is considerable difference of opinion. There is, however, general agreement that the true altitude attained by the airplane is in general not a true measure of its high altitude performance. This fact becomes obvious when it is remembered that the actual or absolute altitude depends not only upon the temperature at the altitude of flight but upon the mean temperature of the air column below the airplane.

In the case of balloons the best performance is measured by the lowest air density reached. The balloon attaining a given lowest air density may not attain the same altitude at one time of year as at another.

Thus it appears preferable to retain the method of comparison utilizing a standard atmosphere. The altitude now necessary to break the unlimited altitude record for either airplanes or balloons is well into the stratosphere in which the air temperature can be considered constant. In these cases the lowest pressure attained gives a reasonably accurate index of the performance of either balloons or airplanes.

In the case of records in other categories now at lower altitudes, the method of determining the altitude of airplanes in the standard atmosphere should follow one of the methods of reduction used by aeronautical engineers. As it is unlikely that general agreement upon the proper method can be obtained, the simplest solution is to retain the lowest pressure attained, converted to altitude in the standard atmosphere, as the measure of performance.

Details of record breaking flights or those otherwise of interest are given in tables II, III, IV, and V.

TABLE II. *Airplane flights to highest altitude.*

Pilot	Country	Date	Lowest Pressure mm. Hg.	Corresponding F.A.I. Altitude Feet
J. A. Macready	U.S.	Sept. 28, 1921	178	34563
S. Lecointe	France	Oct. 30, 1923	161.5	36555
J. A. Macready	U.S.	Jan. 29, 1926	146	38704
C. C. Champion	U.S.	July 25, 1927	147.5	38491
St. C. Street and A. W. Stevens	U.S.	Oct. 10, 1928	152	37854[1]
A. Soucek	U.S.	May 8, 1929	143	39140
W. Neuenhofen	Germany	May 25, 1929	126	41794
A. Soucek	U.S.	June 4, 1930	118	43166
C. F. Unwins	England	Sept. 16, 1932	113.5	43976
G. Lemoine	France	Sept. 28, 1933	109	44822
R. Donati	Italy	April 11, 1934	96.5	47352

[1] By barometric formula from pressure and temperature observations 39606 feet
By camera method 39250 feet

TABLE III. *Seaplane flights to highest altitude.*

Pilot	Country	Date	Lowest Pressure mm. Hg.	Corresponding F.A.I. Altitude Feet
S. Lecointe	France	March 11, 1924	225	29462
V. Demougeot	France	March 28, 1927	215	30479
C. C. Champion	U.S.	July 4, 1927	151	37995
A. Soucek	U.S.	June 4, 1929	147	38560

TABLE IV. *Balloon flights to highest altitude.*
(Open Gondola.)

Pilot	Country	Date	Lowest Pressure mm. Hg.	Corresponding F.A.I. Altitude Feet
Suring and Berson	Germany	July 31, 1901	170.5(?)	35424 (10800 m)
H. C. Gray	U.S.	March 9, 1927	235	28510
H. C. Gray	U.S.	May 4, 1927	122	42470[1]
H. C. Gray	U.S.	Nov. 4, 1927	122	42470[2]

[1] Not recognized as a record because Capt. Gray jumped from balloon before landing.
[2] Not recognized as a record. Capt. Gray was found dead in the gondola and it was therefore presumed that he did not navigate the balloon to a landing.

TABLE V. *Stratosphere balloon flights.*

Pilots	Country	Date	Volume of Balloon cu. ft.	Lowest Pressure mm. Hg.	Corresponding F.A.I. Altitude Feet
Piccard and Kipfer	Belgium	May 27, 1931	500,000	78	51775
Piccard and Cosyns	Belgium	Aug. 18, 1932	500,000	73	53153
Prokovieff, Birnbaum, and Godounoff	U.S.S.R.	Sept. 30, 1933	860,000	49–50	61237
Settle and Fordney	U.S.	Nov. 20, 1933	600,000	49.5	61237[1]
Fedossejenko, Vassenko, and Oussyskine	U.S.S.R.	Jan. 30, 1934	882,850	(Altimeter reading)	72200
Kepner, Stevens, and Anderson	U.S.	July 28, 1934	3,000,000	51	60613[2]
Cosyns and Van d. Elst	Belgium	Aug. 18, 1934	500,000	74	52867
Piccard and Piccard	U.S.	Oct. 23, 1934	600,000	59	57579

[1] Present world's record.
[2] By barometric formula from pressure and temperature observations, 62720 feet.
By vertical camera photographs, 62100 feet.

Third Annual Meeting
Of The
Institute of the Aeronautical Sciences

The Third Annual Meeting of the Institute of the Aeronautical Sciences was held in the Physics Building of Columbia University, New York City, on Tuesday and Wednesday, January 29–30, 1935. The facilities of the Physics Building and the Faculty Club were made available through the courtesy of Columbia University and Prof. George B. Pegram of the Physics Department. The Technical Sessions covered a two day period, beginning at ten o'clock each morning and continuing until one o'clock, when the members lunched at the Faculty Club. The Technical Sessions then continued until six o'clock on Tuesday and until five o'clock on Wednesday, when the Annual Meeting of the members of the Institute was held.

At seven o'clock Wednesday evening the Third Annual Dinner was held at the Faculty Club. About three hundred members and guests attended the meetings.

Technical Sessions

The program for these two days covered a wide range of professional interests and is much too extensive to be fully reported in the Journal. As might be expected, some interesting and significant views on the present status and trends of our knowledge in the field of the aeronautical sciences were developed in discussion and are unavailable for publication. However, so far as practicable, abstracts and digests that should be useful to members unable to attend the meeting are printed in this issue.

METEOROLOGY

W. R. Gregg, Chief, U. S. Weather Bureau, outlined the status of aeronautical meteorology and the plans of the Weather Bureau to develop improved services for air transport. Mr. Delbert M. Little, Chief, Aerological Division, U. S. Weather Bureau, expanded this subject in greater detail. Dr. James H. Kimball, also of the Weather Bureau, discussed oceanic weather and Dr. Irving P. Krick of the California Institute of Technology developed the necessity for better identification of air masses for use on synoptic charts. Prof. C.-G. Rossby outlined a new method for analysis of turbulence and velocity distribution in the boundary layer of the atmosphere and Prof. H. C. Willett spoke on his recent work on atmospheric cross-sections.

D. M. LITTLE
U. S. Weather Bureau

Recent Developments in Meteorological Service for Airways. The year 1934 will no doubt go down in aviation history as the year of reorganizations. The Weather Bureau airway weather service was not an exception. Reduced funds at the beginning of the year required a reorganization to effect economies which reduced the number of weather reporting stations, the number of wind-aloft observing stations, and the commissioned personnel assigned to airport stations.

As an aid in improving the forecasts a start was made in applying the so-called air mass analysis and frontal methods to synoptic meteorology for the airways. Literature and maps were placed in the hands of commissioned field employees. Weekly or semi-monthly symposiums on the new methods were organized at several of the field stations. Meteorologists, trained in these new methods, were recently brought into the Bureau for the purpose of slowly extending the new methods throughout the service.

On July 1, last, the Weather Bureau in cooperation with the Navy and War Departments inaugurated daily airplane weather observations at 21 widely scattered stations in the United States, and one in the Hawaiian Islands, The flights have been made daily whenever possible, since that time, to altitudes of 17,000 feet above sea level and autographic records obtained of temperature, atmospheric pressure and humidity by means of aerometeorographs, together with such information as the thickness of cloud strata, the elevations of icing conditions, etc. These data are transmitted promptly over the teletype circuits in considerable detail by means of a readily decipherable numeral code. Necessary changes had to be made in the existing teletype schedules to provide time for these transmissions. With the extension of air mass analysis methods, it is probable that additional data such as poten-

tial temperature, specific humidity, etc., will need to be included in these reports. The airplane weather observation data are not only of great value to the Weather Bureau meteorologists but have been used to a considerable extent by the air transport companies.

From the beginning of the airway service, the barometry problem has been a rather difficult one. Funds were not available for the installation of mercurial barometers, including the cost of running levels to establish their elevations at airway stations. It was therefore necessary to resort to the use of aneroid barometers. Detailed instructions were prepared for the preparation of tables for the reduction of the pressure to sea level in accordance with the methods devised by Bigelow. Considerable work is yet to be done but it is hoped that within the next year the accuracy of reduced to sea level pressures from aneroid barometers will be closely comparable with that obtained from mercurial barometers.

Another promising project has been inaugurated over the plateau and Pacific coast regions through the cooperation of United Air Lines. The pilots make observations of free air temperatures over intermediate airway weather reporting stations, recording the name of the station and the altitude of the observation in each instance. Additional data are recorded such as the elevation of the upper surface of cloud layers, the levels at which icing is encountered, the elevations of temperature inversions, including temperatures through inversions and other interesting phenomena. The observations are given to the Weather Bureau airway forecast centers after the transport planes land.

J. H. KIMBALL
U. S. Weather Bureau

Oceanic Weather. Dr. Kimball exhibited by slides, a series of North Atlantic charts showing pressure distribution daily for the period January 19–26th, 1935. The period was chosen to show the *sufficiency* of the radio collection of weather observations in outlining major pressure irregularities, and to indicate the direction and velocity of the principle air streams from the surface to an elevation of 2000 feet; also to show their *insufficiency* in depicting less general, but still important, pressure irregularities as well as all weather elements other than wind, and the situation above the low eloud level. He aimed to show that the collection of data was as yet insufficient for the appraisal of the weather hazard to a routine transatlantic air service. The charts, showing a period of only moderate storminess, were used to indicate inferentially the hazard to aircraft when the frequent storms of gale proportions prevail; and to show persistent storminess in a not infrequent pressure pattern over long stretches in the normally moderate weather between Bermuda and the Azores.

Another series of daily maps selected from those of 1927 and made up from a plentiful collection of observations received through the mails was shown to suggest the scatter of reports that might be available if the radio collecting service were expanded to reasonable proportions and to show the pressure distribution and associated weather chosen for nearly all of the successful west to east transatlantic airplane crossings.

S. M. SEREBRENY AND J. EDMUND WOODMAN
New York University

An Institute of Aeronautical Meteorology. New York University is planning the development of a research center at University Heights, definitely devoted to the aeronautical phases of meteorology. This is in the belief that there is room for such a body, whose chief activities will be applied directly or indirectly to aviation and the various lines of aeronautic industries and business. It will not in any sense compete with existing bodies.

Its physical basis rests upon the laboratories of the Guggenheim School and their equipment; and upon the just completed meteorological observatory, which is to be used as a regular ground and airway station by the U. S. Weather Bureau. The location of this station is ideal from the viewpoint of ground studies as the northernmost in a network made by a dozen or more existing stations in or near New York. It is ideal also from the viewpoint of upper air work, forming the apex of a nearly equilateral triangle whose base runs from Mitchel Field to Newark Airport.

H. C. WILLETT
Massachusetts Institute of Technology

Atmospheric Cross-sections. This paper is being published in full in a future issue of the Monthly Weather Review, so that only a brief resumé need be given.

The term "atmospheric cross-section" is defined, and a brief explanation given of the method of preparation of the observational data for use on such a cross-section. The proper choice of the meteorological elements whose fields are to be represented on the cross section is discussed, and the method of analysis of the data represented is briefly indicated. This is followed by a consideration of the three standard atmospheric cross sections chosen for daily prepe-ration at the Massachusetts Institute of Technology. The paper is concluded with the presentation as illustration of the three standard cross sections for December 7 and for December 8, 1934, and with a brief discussion of the facts of especial meteorological significance indicated by these particular cross-sections.

C.-G. ROSSBY
Massachusetts Institute of Technology

A Note on the Turbulence Problem. In 1932 the writer applied von Kármán's principle of similarity to the velocity distribution in the layer of frictional influence of the atmosphere. The solution thus obtained could not be extended down to the surface of the earth. Since that time an attempt has been made to supplement the earlier solution with a solution applicable to a sub-boundary layer within which the frictional drag is independent of height and the mixing length proportional to the distance from the ground. Requiring continuity in stress, mixing length, and velocity the two solutions may be combined. The final theory describes in a fairly satisfactory way the variations in surface wind direction with roughness and gradient wind velocity. The theory leads to a definite expression for the height of the turbulent layer which agrees fairly well with the results of airplane observations at Boston. Additional confirmation of the theory is obtained from the observed depth of the wind-stirred surface layer of the ocean.

The effect of stability on the wind distribution next to the ground is taken into account with the aid of a crude energy consideration. Comparing two cases of flow under equal stress, one case with stability (S) the other with adiabatic lapse rate (a) it is found that a fixed level z,

$$l_S = \frac{l_a}{\sqrt{1+\frac{1}{\left(\frac{\partial U}{\partial z}\right)_S^2}\frac{\beta g \partial\theta}{\theta \partial z}}},$$

$$\left(\frac{\partial U}{\partial z}\right)_S = \left(\frac{\partial U}{\partial z}\right)_a \sqrt{1+\frac{1}{\left(\frac{\partial U}{\partial z}\right)_S^2}\frac{\beta g \partial\theta}{\theta \partial z}},$$

where l_a, the mixing length in the adiabatic case, is given by

$$l_a = 0.4z.$$

From Heywood's wind measurements the non-dimensional constant β is found to have a value of about 40. The theory is to some extent confirmed by an analysis of Hellman's wind measurements at Nauen and by a study of the diurnal variation in the surface wind direction.

IRVING P. KRICK
California Institute of Technology

Air Mass Symbols for Use on Synoptic Charts. When using air mass and frontal methods of weather analysis, it becomes important to describe the types of air involved as accurately and as simply as possible. The symbolization used should convey to the weather forecaster the following information: (1) the geographical source region of the air masses; (2) their life history after leaving the source region until their arrival at the point of observation, and (3) their vertical structure at the time of observation. This last becomes particularly important, as the interactions of the various air masses along their boundary surfaces or "fronts" are dependent in a large measure upon their vertical structures, the knowledge of which enables the forecaster to anticipate the intensity of frontal phenomena. All of this information must be presented in a form simple enough to be used effectively on synoptic charts.

The geographical source region and life history of an air mass may be indicated by an elementary two-letter symbol with appropriate subscripts indicating the time over land and water surfaces required by the air in making the journey from a source region to the point of observation. The structure of the air at the time of observation, when airplane flights are available, may be indicated by a symbolization above and to the right of the designation just described, which will convey to the forecaster in terms of a conservative air mass property the degree of stability of the air together with indications of changes in structure which will arise if the air be subjected to vertical accelerations. This is done through the use of the rate of change with elevation of the equivalent potential temperature and an indication of the mechanical lifting necessary to completely saturate the layer under consideration. When the airplane sounding pierces a frontal surface, this symbolization is used for the air masses below and above the front, and when the upper air information is complete over the entire country, this procedure enables the forecaster to visualize the synoptic situation from a three-dimensional standpoint.

RADIO

In the session on aeronautical radio, presided over by Dr. Lewis M. Hull, a very comprehensive survey was developed concerning the many present applications of radio in aircraft operations. In particular, Harry Diamond of the Bureau of Standards described the beam system for blind landings, outlined the development through which the apparatus has passed to date, and the difficulties overcome. The practicability of this system was demonstrated in tests by several air transport lines of installations at Newark, New Jersey, and Oakland, California. In its present stage of development, it provides a number of technical and economic refinements over these experimental installations. The alternative radio compass system for blind landings, due in large part to Captain Hegenberger, has been applied in experimental service both by the Army and the Department of Commerce.

Lt. Col. Wm. R. Blair of the U. S. Signal Corps discussed automatic radio transmitters for use on unmanned sounding balloons to obtain meteorological data in the upper air. Such use is now well within the state of the art and should prove valuable when other methods are impractical. In time of war, both the artillerist and the Air Corps will need upper air data behind the enemy lines.

Reeder Nichols carried the meeting, in spirit, through the MacRobertson Race to Australia and gave members a vivid impression of what it is like to be lost at night somewhere over India, with a limited fuel supply, and no hope of a safe landing unless a red-tape-bound official could be persuaded by radio to use his own radio equipment as requested. It took an SOS call to clear the air and get a position determined. Again, when communication with the nearest ground station was lost due to heavy atmospherics on long wave, San Francisco was asked to stand by for distress signals on 36 meters, the distance at that time being 8600 miles.

H. C. LEUTERITZ
Pan American Airways

Radio Problems Applied to Air Transport. The paper was based on the results obtained during seven years of experience in setting up and organizing the communications system for Pan American Airways. The requirements for such a service were then mentioned as consisting of aircraft service, weather service, navigation, traffic reservations, flight orders and administration messages. The next point mentioned was the apparatus aboard aircraft, type of system to be used whether telephony or telegraphy and some of the reasons for selecting telegraphy, the question of reliability of equipment, weight and cost relative to the initial capital investment as represented by the aircraft itself. The next point discussed was the ground apparatus, covering the ease of operation of the equipment, stressing the factor of simplicity and reliability and also stressing the need of adequate power supply to make it possible to operate the station during emergency periods when serious storms have made the local power supply totally unreliable. Instances were cited of cases when our stations were the only ones in operation during severe storms and were the only means of communicating with the outside world advising it of the suffering and needs of the populace, and which in a great measure were handled by means of the aircraft service itself.

Radio Transmission in Relation to Aeronautics

Presented at the Radio Session, Third Annual Meeting, I. Ae. S.
LLOYD ESPENSCHIED, *Bell Telephone Laboratories*

THE object of this paper is to give a *general* picture of the radio frequency spectrum, particularly to compare the various portions of the spectrum in respect to transmission effectiveness. The factors affecting radio transmission are many and complex. It should be understood, therefore, that a simple generalization of the subject is undertaken at the expense of detailed accuracy and thoroughness.

In considering radio transmission we are concerned with two variables: One, the electrical noises that occur as a results of atmospheric disturbance; and the other, attenuation of the signal with the spread of transmitted energy, its absorption in the earth and upper atmosphere, and its redistribution as affected by ground reflections.

Considering, first, the undesired noise, we shall limit our considerations to the noise which arises from atmospheric sources, principally lightning discharges. The other general source of noise from industrial sources is so varied in character and so much a matter of specific instances that it does not lend itself readily to general treatment; furthermore, being man-made in origin, it is more or less subject to control. In general, atmospheric noise throughout the radio spectrum decreases with increase in

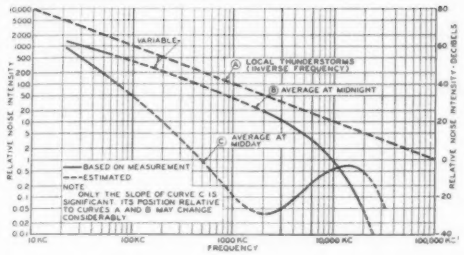


FIG. 1. Relative variation of radio noise intensity with frequency for northeastern United States as measured on simple vertical antenna.

frequency. This effect is well illustrated by Curve *A* in Fig. 1,[1] which is for the reception of noise from a nearby thunderstorm. Curve *B* for midnight conditions shows a trend with frequency which is similar to that of Curve *A* except at the higher frequencies where the overhead ionization conditions limit transmission. Curve *C* for midday conditions shows a rise in the static level corresponding to the short-wave range. This is due to the fact that for these waves reflection from the ionosphere becomes prominent, enabling them to propagate over great distances by so-called sky-wave transmission. The greater transmission range of these waves means that the static is collected from over a greater area, resulting in an increase in the noise level corresponding to the improved effectiveness of the waves in this portion of the frequency spectrum. At frequencies higher than those shown in the chart, the noise level from atmospheric sources continues to decrease.

As the second major consideration, that of the transmission effectiveness of the radio spectrum to desired radio waves, the general picture is summarized fairly well in Fig. 2.[2] At the very high frequencies shown at the top of these curves, the propagation might be characterized as

[1] R. K. Potter, *Frequency Distribution of Atmospheric Noise*. Proc. I. R. E., Vol. 20, No. 9, p. 1514, Sept. 1932. This drawing was also used in answering Question No. 4 at the Third C. C. I. R. Meeting at Lisbon, Portugal, 1934.

[2] Drawing prepared from figures in Bureau of Standards Circular Letter No. 317, Jan. 25, 1932, which were presented also in answering Question No. 4 at the Third C. C. I. R. Meeting at Lisbon, Portugal, 1934.

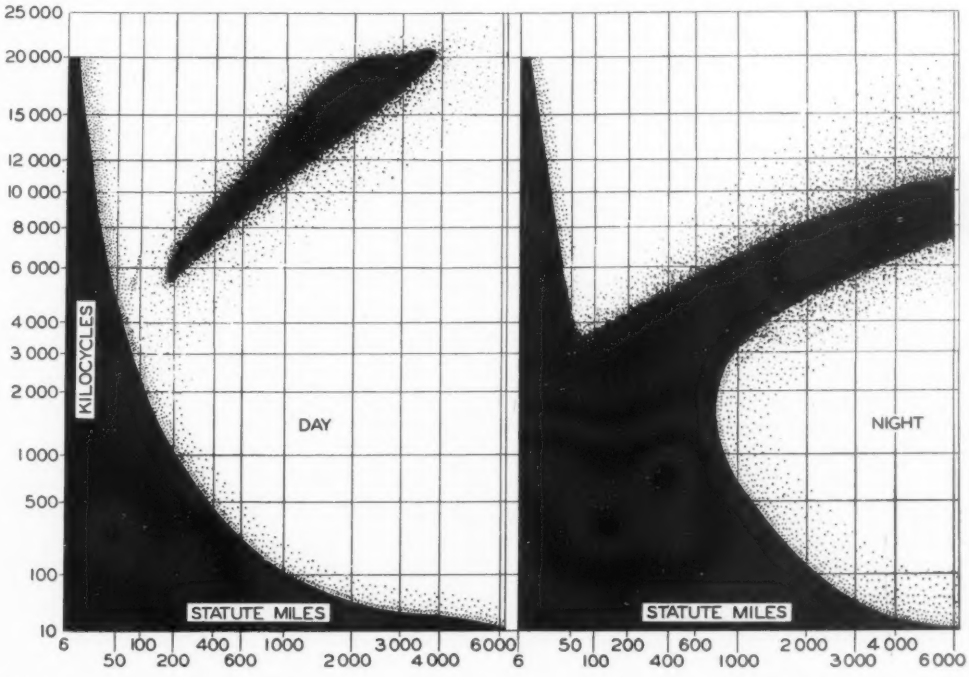


FIG. 2. Approximate distance ranges of radio waves. 1 kilowatt non-directional radiation. Useful ranges lie within black areas.

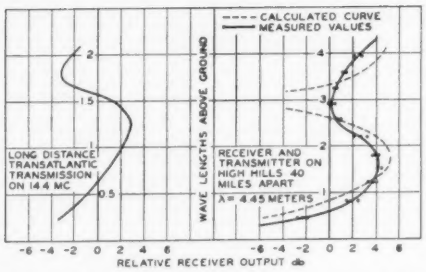

CALCULATED CURVE
MEASURED VALUES
WAVE LENGTHS ABOVE GROUND
LONG DISTANCE TRANSATLANTIC TRANSMISSION ON 14.4 MC
RECEIVER AND TRANSMITTER ON HIGH HILLS 40 MILES APART
λ = 4.45 METERS
RELATIVE RECEIVER OUTPUT db

FIG. 3. Receiving antenna output vs. transmitting antenna height.

direct-ray propagation in which the distance of transmission is limited largely by the curvature of the earth, ordinarily to some tens of miles. As the frequencies decrease, the range of transmission increases somewhat and then, rather suddenly, enormous distances are covered, by virtue of sky-wave propagation, indicated by the rather abrupt reaching out of these curves. This long-distance sky-wave propagation occurs at somewhat lower frequencies during the night than it does during the day. The frequency range around 3 mc., which is utilized by the air transport lines for night transmission, is observed to propagate to hundreds of miles at night, but to be limited to much shorter distances during the day because of atmospheric absorption. Correspondingly, the 6 mc. range of frequencies, utilized for daylight transmission by the air transport companies, extends to several hundred miles, but includes a variable skip region beyond some 50 miles which may make service at these distances uncertain during the morning or evening hours. At nighttime this same frequency range transmits to much greater distances. We observe also in this figure that for frequencies below the broadcast range of 1 mc. or so, the transmission distance again increases to great distances. There are indications that at these great distances the lower frequencies are likewise obtained largely by virtue of sky-wave transmission as are the higher frequencies at the corresponding distances.

Reception of sky-wave transmission is characterized by waves incident upon the receiving antenna downcoming at an angle with the horizontal, ordinarily of the order of 10 to 30 degrees. The net effect upon the receiving antenna is the resultant of direct downcoming waves and waves reflected from the earth's surface. The phase relation between these two components and, in turn, the output of the receiving antenna, changes with height above ground. This effect and the general magnitude of it in db are illustrated in Fig. 3.[3]

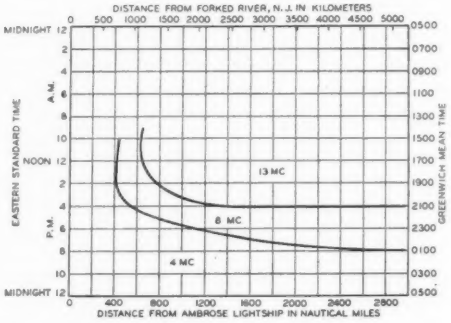


FIG. 4. Ship–shore radio telephony—Estimated optimum use of radio frequency bands. Spring and fall. Areas separated by curves represent preferred frequencies for hours and distances indicated.

Fig. 4 illustrates a chart which has been found to be of practical usefulness in the operation of telephone service with ships at sea by means of short waves. In setting up a circuit, it is important to choose the appropriate frequency of transmission, depending upon the distance to the vessel and the time of day. This chart indicates, for example, that for a vessel 1000 miles out, for transmission during midday a frequency of 13 mc. should be used, whereas at 4 P.M., 8 mc. should be used and, later in the evening, 4 mc. Some corresponding guide to the use of frequencies will probably be needed when avaiation service is extended across the seas, requiring radio transmission over these longer distances.

[3] C. R. Englund, A. B. Crawford, W. W. Mumford, *Some Results of a Study of Ultra-Short-Wave Transmission Phenomenon*. Proc. I. R. E., Vol. 21, No. 12, pp. 481 and 482, March, 1933.

INSTRUMENTS

E. A. Sperry, Jr. acted as chairman in place of Capt. A. F. Hegenberger. Mr. Sperry in his opening remarks stated that he had never before seen such a representative group gathered together to discuss instruments and that aircraft instruments should be greatly improved in the future due to the functioning of the Institute in this manner. He then called attention to the entrance of a new group to the aeronautical instrument field, namely, a group at the Massachusetts Institute of Technology. This group had for some time been doing research work on aeronautical instruments and at this meeting were presenting the first papers on their work. The three constituting the group were Messrs. C. S. Draper, J. R. Markham, and W. McKay.

Mr. Sperry then introduced Mr. Draper who presented in a paper a novel way of mathematically evaluating the dynamic characteristics of aircraft instruments, whereby improvements can be predicted mathematically rather than by the old methods of cut and try.

C. S. DRAPER

Massachusetts Institute of Technology

Dynamic Characteristics of Aircraft Instruments. All aircraft instruments are subject to dynamic errors. It is, therefore, important to know the dynamic characteristics which describe the response of an instrument to rapidly changing conditions. The proper interpretation of results from one or two simple experiments often makes it possible to predict the behavior of an instrument under any circumstances with reasonable accuracy. This same analysis also indicates possible improvements and the modifications which should be made in the instrument mechanism.

A satisfactory instrument must be so constructed that there is a unique relation between the position of an indicating element and each value of the physical quantity to be measured. In general, then, each instrument will be a system with one degree of freedom and may be treated by the methods already developed for such cases. For a particular instrument the procedure requires a study of the motion of some suitable part of the mechanism by summing up the effects of deflection, velocity and acceleration to obtain

$$\text{(effect of acceleration)} + \text{(effect of velocity)} + \text{(effect of deflection)} = \text{(effect of external influences)} \quad (1)$$

The terms of Eq. (1) may have any consistent dimensions, although in any particular analysis the initial equation usually represents a sum of forces or torques.

It is seldom possible to write a mathematical expression which accurately represents the motion of an instrument mechanism over its entire range. However, graphical methods are available which may always be applied in complicated cases. Good results may often be obtained from Eq. (1) by the use of expressions which are mathematically simple, but only approximately in agreement with the physical facts. Applied to the displacement from equilibrium of some proper part of an instrument mechanism, the usual assumptions are; (1) inertia effects are proportional to acceleration, (2) friction effects are proportional to velocity and (3) elastic effects are proportional to displacements from equilibrium so that (1) becomes

$$a_2 \frac{d^2x}{dt^2} + a_1 \frac{dx}{dt} + a_0 x = \text{(externally applied force)}. \quad (2)$$

Obviously Eq. (2) will be valid over a range which depends upon the case considered. In any case (2) will be valid over a sufficiently short range of operation. Thus within proper limits, if the variation of the externally applied force may be handled mathematically, the general instrument problem may be reduced to the treatment of an equation whose solutions are well known.

The three coefficients of Eq. (2) may be found experimentally from static experiments and from observations made as the deflected mechanism returns to equilibrium under no external force. An experimental check is always desirable in order to define the limits within which Eq. (2) is a satisfactory approximation.

J. R. MARKHAM

Massachusetts Institute of Technology

Dynamic Characteristics of Airplane Instruments. In deviations from steady flight aircraft instruments whose operation depends on a pressure difference have a tendency to lag. This lag is due to mass damping and restoring constants of the instrument mechanism. The determination of these constants would greatly facilitate the application of mathematical theory to instrument design. It is possible to determine these constants experimentally by studying the motion of the instrument hand as it returns to its zero position after an initial displacement. With most instruments, however, this motion is so rapid that the motion must be observed photographically. Apparatus has been constructed which consists of a chamber in which the instrument to be studied may be observed through a window. The volume of the chamber and hence the pressure may be varied by the movement of a large sylphon bellows directly attached to the chamber. Suitable openings to the chamber are arranged to which manometers, vacuum pump, sensitive diaphragm etc. may be connected by means of which initial and varying pressures may be set and observed. In addition, a plug is fitted to a large opening so that when it is suddenly removed the pressure in the chamber can instantaneously return to room pressure. By means of this device a given deflection of the instrument hand may be set. The pressure may be suddenly changed to zero by removing the plug. The resulting motion of the instrument hand is obtained by a high speed camera. The record may be plotted, thus obtaining the transient vibration or motion of the instrument. If a known variation in pressure is applied to the instrument it is possible to check the reading of the instrument with what it should read. The pressure may be varied by means of a cam, designed for a given pressure

change and attached to the sylphon bellows. Calibration of the pressure change is obtained by a pressure diaphragm which has no dynamic error. From this a plot showing actual pressure to which the instrument is subjected and the actual instrument reading versus time may be obtained. Knowing the constants for the instrument it is possible to calculate the performance of the instrument for a given flight condition. This performance may be checked by designing a cam to represent the flight condition and imposing the condition on the instrument.

WALTER McKAY
Massachusetts Institute of Technology

Dynamic Coefficients of the Aircraft Magnetic Compass. Beginning with a simple case, the torques which act on a compass card during a free oscillation, that is, during a return to equilibrium after an initial displacement, are analyzed. Motion of the bowl which causes extraneous forces to act on the card resulting in speed error, northerly turning error, swirl error, etc., are not considered. The attempt is made to include these factors after the simpler analysis has been completed.

For a free vibration of the card, the torques may be summed up thus:

$$\text{inertia torque} + \text{total viscous torque} + \text{magnetic torque} = 0.$$

Inertia torque is given by $I\alpha$ where I is the moment of inertia of the card and α its angular acceleration. Magnetic torque is given by $MH \sin \theta$ where M is the magnetic moment of the card, H the horizontal component of the earth's field, and θ the angular deflection from the magnetic meridian. The total viscous torque is made up of two parts, the static viscous torque and the dynamic viscous torque. Static viscous torque is given by $b\omega$, where b is the static damping coefficient and ω is the angular velocity of the liquid. The dynamic viscous torque is that due to the non-uniform distribution of velocity in the liquid and is a direct measure of swirl error in the compass. We now have:

$$I\alpha + b\omega + \text{dynamic viscous torque} + MH \sin \theta = 0.$$

The coefficients I, b, M and H are determined by simple physical measurements. The relation between θ, ω and α is obtained by graphically differentiating a displacement-time curve found by plotting the return of the card to equilibrium from an initial deflection of, say, 90 deg. All torques in the above equation are then determined with the exception of dynamic viscous torque which may be calculated by algebraic addition.

External forces may now be added to the analysis to give the actual service condition. Due to analytic complexity, graphical solution gives the most feasible method of handling the problem.

P. R. BASSETT
Sperry Gyroscope Company

The Automatic Pilot. During the past year, we have at last had an opportunity of studying the value of airplane automatic pilots in service. There is nothing very new in the automatic pilot for airplanes, as we have been obtaining experience with it experimentally for a period of twenty years, and have accumulated a great deal of data regarding the performance of various types of mechanisms. This year, however, with over twenty pilots in daily use, we are obtaining new information as to the service that the automatic pilot can render to the human pilot. One of the most useful services is proving to be relief to the human pilot of the energy necessary in flying the ship at high altitudes. It is well known that it becomes increasingly difficult for a pilot to perform many duties as he operates at altitudes above 10,000 feet. In order to devote full attention to navigation, meteorology, two way radio, etc., it is of the greatest relief to have the physical effort of flying the airplane removed.

Another unexpected advantage which the pilots are utilizing is the ease with which a long steady glide can be carried out with the automatic pilot. In coming in to an airport from a high altitude, the glide can be made by setting the automatic pilot at a rate of descent which does not cause discomfort to the passengers.

JAMES H. DOOLITTLE
Shell Petroleum Corporation

I wish to corroborate what Mr. Bassett has just said about high altitude flying and the difficulty of the human pilot performing the many necessary duties while at high altitudes. In a recent flight across the continent, I flew for eleven hours at an altitude of 16,000 feet, and found the greatest difficulty in trying to both fly the ship and keep up two way radio communication. I think that the automatic pilot will prove to be a great advantage to safety on this account.

CLYDE SMITH
Bureau of Aeronautics, Navy Department

In the discussion of the papers, Lieutenant Clyde Smith of the U. S. Navy emphasized the point that mathematics and pure science may play an important part in the development of aeronautical instruments, but at the last analysis aeroplane instruments must be developed by actual experience in flying and that he had repeatedly found in his flying experience that the instruments did not behave at all in a manner which theory or mathematics would indicate.

METALLURGY

This session, presided over by Prof. A. V. de Forest of the Massachusetts Institute of Technology, was devoted to a survey of the effect on aeronautical construction of recent metallurgical advances in stainless steels, alloy steel tubes, and aluminum alloys and the means for their welding and physical testing. Special attention needs to be given to the fatigue properties of these materials rather than the conventional static tests for strength.

A. V. de FOREST
Massachusetts Institute of Technology

Dynamic Testing Applied to Metallurgical Development. In making improvements in any engineering material, the measure of progress has heretofore been largely by means of static testing machine results. In actual application, endurance under repeated loads and ability to withstand accidental overloads are the important qualities.

In the case of aeronautics, this makes the plane or engine, or both, into a testing machine for applying the unknown dynamic load conditions. If the development is successful, and both design and material are adequate, an immediate success results. If, however, failures occur they are apt to wreck an extremely expensive testing device.

The outstanding difference between resistance to fatigue and resistance to static forces is the enormous importance of surface conditions in the presence of fluctuating loads. Tool marks, grinding marks, the surfaces of decarbonized forging, the effects of slight corrosions, as well as stress concentrations due to design, are of predominating importance under fatigue loads, and are not revealed by the usual static tests.

In the problem of dynamic strength, two conditions must be fulfilled. In the first place, the metal must be continuous, that is, must have no surface discontinuity such as seams, hair cracks, grinding cracks or quenching cracks at critical sections, and the load itself must be below the fatigue strength of the material. Methods of measuring both these factors are relatively new but much progress has been made within the past year in regard to these factors.

It is expected that the new laboratory at the Massachusetts Institute of Technology will develop further methods of measurement and testing.

LLOYD HOPKINS
American Chain Company

Recent Developments in Aircraft and Engine Control Cables. The early designers and builders of airplanes depended a great deal on the use of cold drawn steel wire, first because of its availability, second because of its uniformity and dependability, and third because of its high strength: weight ratio. The Glenn Martin Clipper Ship carries as essential flying controls, motor controls, and anchor ropes, approximately 252 pounds of cable. Compare this with the live load for which the early ships were designed. This 252 pounds is equivalent to about 5140 ft. of cable, or about 116 miles of wire. The use of the 7 strand 19 wire construction for flying controls has in America persisted from the early days. For small cable, this construction affords the greatest strength : weight ratio combined with the flexibility necessary for small pulley operation. As the cables invariably failed by fraying at the point of operation around the pulleys, it was recognized that the major stresses which determined the life of cable were those of repeated bending. The Materiels Section of the Army Air Corps at Wright Field[1-2] started endurance testing control cables prior to 1927, and as a result, Army (and later, Navy) purchasing specifications were promulgated. The conditions imposed by the endurance test are, briefly, that after the cable has been subjected to the specified number of reversed bends or oscillations around the specified pulley, it shall develop at least 50% of the original nominal breaking strength.

Tests at Wright Field[3] demonstrated conclusively that preforming the cables would greatly extend their life. Preforming is a process applied during the manufacture of the cable. At the closing operation each strand is formed into the helix it assumes in the finished cable. This treatment reduces the internal stress existing as residual shear to a minimum.

Early in 1927 the Hazard Wire Rope Company started the manufacture of stainless steel strand and cables primarily for standing and running rigging for yachts. Many of the early installations are still in operation after seven years constant exposure to sea water spray. The alloy selected for this cable is of the type containing approximately 18% chromium and 8% nickel. This alloy has properties making it singularly suitable for the development of rope wire. It is relatively highly corrosive resistant in the cold drawn as well as the annealed state. It develops high physical properties by the process of cold working. It is of the austenitic type and is therefore relatively non-magnetic as compared with other available steels.

The use of preformed stainless steel control cables was adopted by the Army Air Corps for photographic planes in 1931 after service experience and laboratory tests[4] had demonstrated that the developer and hypo solutions used were highly corrosive to ordinary steel control cables. It was found that stainless cables were entirely resistant to the action of the hypo and developer solutions, which were accidentally spilled during flight.

The rusting of steel parts on sea planes has led to the

widespread use of zinc and cadmium plating. It is not however practical to electro-plate the component wires of control cables due to their small size and the difficulty of determining whether or not a satisfactory plate has been applied. Zinc coating by the hot galvanizing process is not suitable as the character of the coating is not conductive to uniformly high fatigue values.[5] It has been the practice to coat carbon steel control cables with a slushing compound. This procedure is, in general, unsatisfactory as cables become dirty, hard to inspect, and often times become rusted under the protective coating.

The corrosion-fatigue properties of stainless steel are notably superior to those of tinned or galvanized carbon steel wire, where the formation of rust pits in service and consequent stress concentration materially lower the life of cables subject to bending. While the development of stainless rope wire has necessarily led to improvement of the fatigue properties of this material, the endurance values are basically lower than for carbon steel. When the element of corrosion is considered, the original endurance value becomes much less important.

The development of stainless wire has led to the development of new methods of testing. The fatigue testing of wire presents peculiar problems. It is not practical to machine specimens. The point of maximum stress should be at the original cold drawn surface. At the same time stress concentration at the grips must be kept low. The apparatus described in A.S.T.M. Proceedings[6] satisfies these requirements.

The desire for a non-magnetic high strength control cable is appreciated by the cable manufacturer. However, it has not been possible so far to consistently meet the magnetic permeability values which have been requested. Dead soft annealed steel of the 18-8 type is wholly austenitic and practically non-magnetic but as it is cold worked it becomes magnetic and the permeability varies upwards approximately in proportion to the critical rate of work hardening which the particular alloy in question exhibits.

Stretch of all cables or ropes may be classified as constructional stretch and elastic stretch. Constructional stretch is caused by the compression of the core and the settling of the individual wires and strands in place when the cable is loaded. The constructional stretch is practically permanent after the rope has been stressed repeatedly. The prestretching process usually consists in loading the cable in straight lengths, after fittings or eye-splices have been applied, to approximately 60% of the breaking strength for periods varying from 24 to 72 hours, depending upon the results desired. It will be found further advantageous to install the cable immediately after prestretching, without recoiling or rereeling.

Elastic stretch is an inherent property of the cable construction and the material of which it is composed. This must be taken into consideration by the designer, and proper allowances made.

The request for prestretched cable having the smallest possible constructional stretch is not consistent with the use of eye splices and light weight grommets as end fastenings. The distortion of these loops results in considerable effective stretch. Properly designed and processed fittings are now available which will insure freedom from stretch at these points. These fittings may be swaged on the cable immediately prior to prestretching and installation.

TABLE I

Cables Tested: 1/8" 7x19 Preformed Tinned Carbon Steel Control Cables
1/8" 7x19 Preformed Stainless Steel Control Cables

Method of Tests:
One series exposed to 150 hours—20% salt spray test
One series tested as received
Both series subject to endurance test Warner Machine: 300,000 reversals of stress—AN-210-3a Phenol-Fabric Pulley 30 lb. load (60# weight)

Comparison

	Carbon Steel	Stainless Steel
Original Breaking Strength	2090 #	1980 #
After 150 hours, salt spray	1835 #	1960 #
Loss in Breaking Strength Due to Corrosion	155 #	20 #
p.c. loss in Breaking Strength Due to Corrosion	7.4%	1%
Original Breaking Strength	2090 #	1980 #
After 300,000 Reversals of Stress	1840 #	1770 #
Loss in Breaking Strength Due to Fatigue	250 #	210 #
p.c. loss in Breaking Strength Due to Fatigue	12%	11%
Breaking Strength After 300,000 Reversals	1840 #	1770 #
Breaking Strength After 150 hours in Salt Spray and 300,000 Reversals	1235 #	1580 #
Loss in Breaking Strength Due to Corrosion-Fatigue	605 #	190 #
p.c. loss in Breaking Strength Due to Corrosion-Fatigue	33%	11%
Original Breaking Strength	2090 #	1980 #
Breaking Strength After 150 hours in Salt Spray and 300,000 Reversals	1235 #	1580 #
Gross Loss in Breaking Strength Due to Combined Effect of Corrosion & Fatigue	855 #	400 #
p.c. of Gross Loss in Breaking Strength Due to Combined Effect of Corrosion & Fatigue	41%	20%

[1] D. A. Warner, *Special Methods of Testing Aircraft Materials*, Aeronautical Engineering, A.S.M.E., Vol. 4, No. 3, p. 141.

[2] *Cable & Pulley Investigation*, Wright Field Report, April 4, 1932.

[3] *Tests on Aircraft Cable*, Wright Field Report, August 11, 1933.

[4] *Corrosion of Various Metals and Alloys by Solutions Used in Aerial Photography*, Wright Field Report, May 5, 1931.

[5] Swanger and France, *Effect of Zinc Coatings on the Endurance Properties of Steel*, A.S.T.M. Proceedings, Vol. 32, Part 11, p. 430.

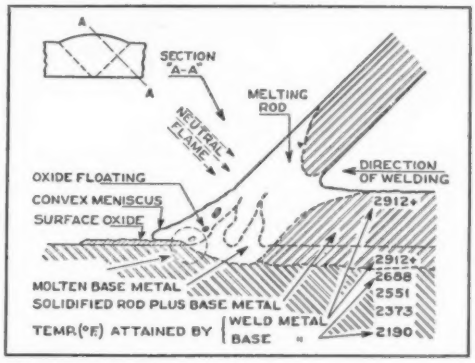
[6] de Forest and Hopkins, *The Testing of Rope Wire and Wire Rope*, A.S.T.M. Proceedings, 1932, Vol. 32, Part 11, p. 398.

R. L. TEMPLIN
Aluminum Research Laboratories

Aeronautical Structural Research. Certain of the fundamental structural research problems being worked upon in the Aluminum Research Laboratories, at New Kensington, Pa., together with the research facilities for investigating kindred problems, are reported. While the work done is

mainly on structural units made from light alloys of aluminnum yet in some instances parallel tests have been conducted on similar steel specimens. The studies include impact tests with quantitative measurements of deflection and strains; measurements of strains and deflections in indeterminate riveted structures; tests of large flat plates under concentrated loads applied over definite areas and with various conditions of edge fixity, supplemented with the theoretical analysis and evaluation of the constants involved; experimental tests on a relatively large number of specimens designed to study the strength and behavior of outstanding plates under edge compression, again supplemented with theoretical analysis; numerous compression tests of thin walled tubes having d/t ratios up to 1200; experimental studies involving many tests, for the purpose of improving the design of large thin-walled storage tanks for liquids, and their supports; tests of more than 800 columns including many built-up specimens; tests of latticed members under various loading conditions; tests of flat and corrugated plates under uniform loads; tests of plate girders with various conditions of web stiffening; tests of stiffened flat plates under bending loads; and natural frequency of vibration tests of structures.

Strain and deflection measuring apparatus include various extensometers, strain gages, and recording devices with suitable calibrating equipment of certified accuracy. The structural tests are supplemented quite fully by determinations of mechanical property values of the materials used. Facilities are available for making precise measurements of elastic modulii, fatigue strengths in repeated tension and compression or for any desirable stress range involving both tension and compression or fatigue at elevated temperatures or repeated torsional stresses; various hardness tests; shearing tests; impact tests; coefficient of friction tests under unit pressures ranging from a few pounds up to 7000 lb. per sq. in. Tensile properties are determined for metals throughout the temperature range −114°F. to 1600°F., and the creep strengths of metals from room temperature to about 600°F.

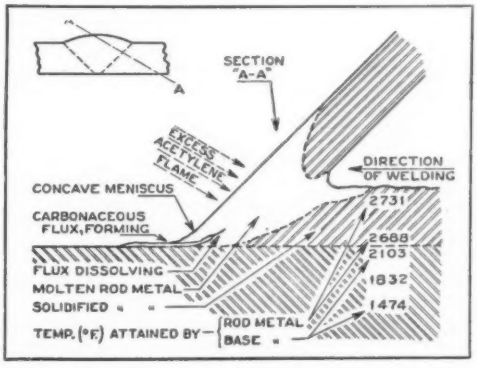


Diagrammatic sketch shows roughly what takes place during neutral flame welding

process and to industry as Lindewelding. The method has been thoroughly tested for aircraft construction and found to possess marked advantages in addition to its elimination of heat cracking. The method possesses the unique ability to produce a weld without the necessity of raising the base metal to its melting point. The self-fluxing process employs the same apparatus as the ordinary method of oxy-acetylene welding but requires a special welding rod and flame adjustment.

The ordinary method of oxy-acetylene welding employs a so-called "neutral" flame which is in reality slightly oxidizing in its effect on the metal. With this method it is, therefore, necessary to melt the base metal to allow the oxide coating to float off, thus permitting metal to metal contact between the welding rod and the parts to be joined.

In the new process, advantage is taken of certain properties of carbon to eliminate the oxide film and thereby ob-

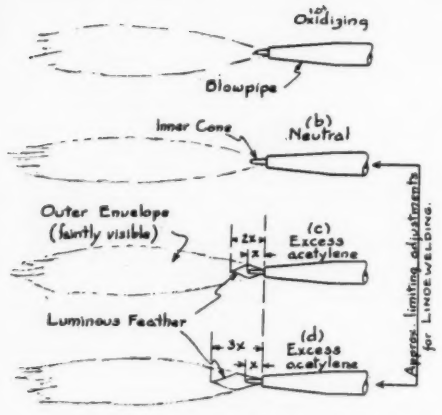


This sketch shows the important points regarding Lindewelding

H. S. GEORGE
Union Carbide & Carbon Company

Tubular Welded Steel Construction. The material almost universally specified in this country for the construction of fuselages and engine mounts has been chrome-molybdenum steel, chiefly in tubular form. The welding of chrome-molybdenum steel presents no unusual difficulties and is the most widely used type of construction.

Chrome-molybdenum steel will not withstand much tensional stress in the temperature range close to the melting point. Tensional stresses in this zone are fortunately infrequent. Occasionally, however, conditions are such as to produce heat cracks. The prevention of heat cracks has, however, been completely effected by a recently developed welding process which operates independently of other expedients. It is known technically as the self-fluxing



THE APPEARANCE OF THE OXY-ACETYLENE FLAME.

viate the necessity for melting the base metal. These properties of carbon; which together form the basis of the self-fluxing process, are as follows: carbon is soluble in iron and is absorbed rapidly by iron at feasible welding temperatures; carbon lowers the melting point of the solution and the melting point of the eutectic mixture coincides with a feasible welding temperature which is several hundred degrees below the melting point of steel; carbon (and the iron-carbon eutectic mixture) reduces iron oxide to iron and a gaseous by-product. The carbon is derived from the oxy-acetylene welding flame by adjusting it to a slight excess of acetylene.

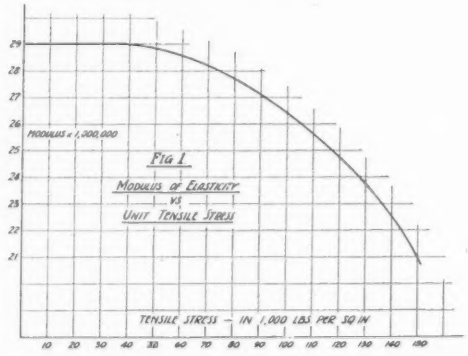
For aircraft welding, the flame and rod are manipulated in the usual manner. The effect of the excess acetylene is to produce a thin film of iron-carbon eutectic alloy about one or two-thousandth of an inch in thickness on the base metal in proximity to the advancing puddle. The combined effect of the excess acetylene flame and the eutectic film is to prevent oxidation of the base metal. Moreover, the film reacts with the usual thin oxide coating found on chrome-molybdenum tubing; reducing it to iron and carbon monoxide which passes off. The carbonaceous film is in reality a flux and facilitates the union of the weld metal to the base metal. The film is dissolved in the puddle without appreciably increasing the carbon content of the weld, because of the minute quantity of the flux.

One more benefit derived from the process will be cited and that is the increased strength it imparts to joints heat-treated after welding. Heretofore, especially in the case of thin sheet and tubing, heat-treated welds invariably failed at the edge of the weld, when subjected to destructive tensile test, because the base metal in close proximity to the weld had been heated to or close to the fusion temperature. The full heat-treated strength of the material could not, therefore, be completely realized, to within 10 to 30 per cent. Welds made by the self-fluxing process, with care to avoid melting the base metal, fail remote from the weld at the full heat-treated strength of the material. Some recent tests of properly heat-treated welded joints showed strength of 150,000 lb. per sq. in., with fractures far removed from the welding zone.

CARL de GANAHL
Fleetwings, Inc.

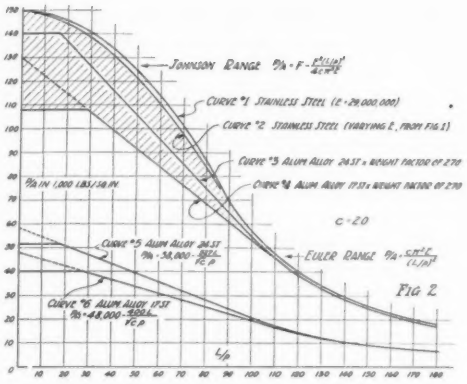
The Future of Stainless Steel in Aircraft. The material, generally known as 18 and 8, is an austenitic alloy of steel containing 17% to 20% chromium and 7% to 10% nickel and generally less than .12% carbon. It can be obtained in sheet, strip, rolled bars and in seamless tubes both round and streamline.

Stainless steel has proven so remarkable in its resistance to corrosion that in the popular mind it has the reputation for being able to withstand anything. This viewpoint is somewhat optomistic and stainless should be used with an understanding of its properties and the conditions to which it is to be subjected. Stainless steel pipe lines as used in the newer battleships have proven unsatisfactory, whereas stainless steel bottoms on seaplanes have never to our knowledge shown any trouble due to corrosion. We have had some of our ribs, trailing edges, and other parts in Privateers Amphibians which operated in Florida for over two years at a stretch. Inspection during fabric renewal has so far shown the stainless to be in perfect condition where other metals suffered severe corrosion under the same service.



There are, of course, other properties of 18 and 8 besides its corrosion resistance which make it useful. Its high electrical resistance and the clean character of its surface provide ideal conditions for electric resistance welding, when done under properly controlled conditions. The Edward G. Budd Manufacturing Company and ourselves have chosen to call such welding "Shotwelding."

Another attractive feature of 18 and 8 is that when obtained in the full hard quality, that is 185,000 pounds per square inch minimum tensile strength, it can still be subjected to severe forming and fabricating processes without damage and it requires no subsequent heat treatment.


JOHNSON RANGE
CURVE #1 STAINLESS STEEL (E = 29,000,000)
CURVE #2 STAINLESS STEEL (VARYING E, FROM FIG 1)
CURVE #3 ALUM ALLOY 24 ST
CURVE #4 ALUM ALLOY 17 ST
C = 2.0
CURVE #5 ALUM ALLOY 24 ST
CURVE #6 ALUM ALLOY 17 ST
EULER RANGE
L/ρ
FIG. 2

It will be noticed that, contrary to prevalent ideas and practice, Young's modulus is not constant. It starts out at 29,000,000 at the initial stress and falls off to 21,000,000 at the yield point of 150,000 pounds per square inch. This at first would appear to be a serious handicap and is a feature usually pointed out with an accusing finger.

In the usual Johnson-Euler curve for steel compression columns throughout the Johnson range the yield point is of primary importance and the effect of the low modulus on the allowable unit stress is almost immaterial.

In the Euler range where the modulus is of importance, the allowable unit stresses have fallen to a point where 18 and 8 again has its high modulus of 29,000,000, and there is no difference between the curve for stainless and any other steel.

It can be shown that the steel and light alloy curves are about equal in the long column or Euler range and that steel has a distinct advantage in the short column or Johnson range, and, therefore, it would seem that structures can be built as light in stainless as in the aluminum alloys, and where the unit stresses are high the advantage is materially in favor of stainless.

AIR TRANSPORT

Major James H. Doolittle presided over the Air Transport session. After hearing Mr. Bassett's paper, which is published in full elsewhere in this issue, Major Doolittle suggested that the Institute might consider organizing a Physiological Section which would consider the new problems which will have to be considered in flying at higher levels.

"It would appear that the physiological aspect of flying has not been given sufficient thought to date. This is especially true in connection with commercial aviation.

"Although the Army and Navy have their flight surgeons who maintain very intimate contact with the pilots and administer to their health and well-being, even so, I do not feel that sufficient thought has been given to the effect of violent and prolonged accelerations, to the effect of rapid changes in pressure and to the effects of undiluted oxygen on the human body, especially over a protracted period.

"It would appear extremely desirable for us to take the physiologists into our confidence and I would even suggest a paper on the physiological aspect of flying from some medical man competent to handle the subject."

W. C. Rockefeller of the California Institute of Technology presented a new method for determining the path which a transport pilot should follow in order to fly between any two points in minimum time. This correlates the known performance characteristics of the airplane with the winds aloft as given by the aerologist at the time the flight is scheduled to start. With high flying and long range flights, substantially improved economy in operation and certainty of scheduled arrival should be possible. A useful abstract of this paper is not practicable and, as it is too long to be published in this issue, it will be held for publication in a future issue.

STEPHEN J. ZAND
Sperry Gyroscope Company

Acoustical Conditions in Airplane Cabins. Serious acoustical work on airplanes started about 1932 with a series of investigations on different types of airplanes.

There are ten principles which must be closely adhered to:

(1) All metal constructions are preferable to fabric because metal will give a transmission loss of about 15 to 17 decibels.

(2) Fourteen-cylinder engines are preferable to 9-cylinder because they give a higher pitch and are generally smoother than 9-cylinder engines.

(3) Three-bladed propellers should be used, preferably of the controllable pitch type and geared in such a way as to give a tip speed at cruising speed of not over 725 feet per second, as at higher tip speed the noise generated by the propeller increases very rapidly, and at speeds above 900 feet per second no acoustical treatment will attenuate propeller noise.

(4) Any engine should be flexibly mounted to provide discontinuity of surfaces. The flexible mounting should be so designed as to take principally a shear load. The mounting should be designed to take loads in any direction.

(5) An exhaust collector should be built in such a way as to exhaust the gases as far away from the cabin as possible. Preferably, a spot should be found where there is a natural shielding of the exhaust pipe by the wing or by the nacelle.

(6) The clearance between the propeller and the structure should be at least twelve inches, and the plane of the propeller should in no case pass through the cabin proper. About eighteen inches to either side of the plane of the propeller a buffer compartment, such as galley, radio room, baggage compartment, or toilet should be provided because

there is a marked directional effect of the sound emitted by the air screw with its maximum approximately in the plane of the propeller. The plane of the propeller should be located in such a way that it will not contain any main bulkheads which, excited by the vibration, would transmit by solid conduction vibratory excitation to the whole fuselage.

(7) Between the cabin proper and the above mentioned buffer compartment there should be a bulkhead with such characteristics that it will not be excited by the vibration. The door should have a very good gasket and closures that will make it absolutely certain no sound can leak into the cabin.

(8) The mounting of windows should permit the windows to flex. The windows should be built preferably of PLEXIDE glass, a glass which is less subject to vibratory excitation than ordinary safety glass. They should be small, as it is acoustically better to have two small windows than one large one of equal area.

(9) The floor should not take any direct loads except the weight of the chairs and should be built in small sections spaced by generous rubber or felt gaskets.

(10) The ventilating system should be built on the principle of an acoustic duct provided with acoustical filters. This applies both to the intake and the exhaust.

After the airplane has been designed along these principles, it should be flown without any acoustical treatment whatsoever. A frequency analysis is then made of the different spots, and materials are chosen which give maximum attenuation at the frequencies encountered in the particular type of airplane. The weight necessary to get a good acoustical treatment varies largely with the type of the ship. It has been our experience that on medium-sized airplanes, up to twenty passengers, about 14 pounds per passenger is necessary. On an eight passenger ship, about 20 pounds per passenger is required.

AERODYNAMICS

This session covered a wide range of problems of great interest largely as a result of prior organization by the chairman, Dr. Clark B. Millikan. Professor Stalker showed an original scheme for boundary layer control. A. M. Stephens discussed spinning research with free models as employed at Farnborough. Dr. Max M. Munk emphasized the importance of the turbulence problem and reported on an experimental investigation undertaken in the Cath. University by Irving Hartmann, published Journ. Franklin Inst., Nov., 1934. The boundary layer of a sphere was heated, and this was enough to influence the entire air motion accordingly, proving that the turbulence originates near the surface.

EDWARD A. STALKER

University of Michigan

Reduction of Drag by Boundary Layer Control. The resistance of a body having a blunt rear end has been studied with boundary layer control exercised through slots. The first experiments were made on a cylinder so that no surfaces of compound curvature would be encountered.

The cylinders had two flat parallel sides, $8\frac{3}{4}$ inches long in the direction of the wind and closed at the front by a semicircular nose of $3\frac{1}{8}$ inches radius. The rear ends were formed with four different proportions, giving a semicircular surface similar to the front surface and three elliptic ends. The major semi axes were, respectively, 5, 7 and 9 inches. The cylinder was 24 inches high.

Boundary layer suppression by suction has been employed on wings and on strut sections. Any force arising from the suction is in the direction of the lift force. If, however, the elimination of the boundary layer is used to reduce the drag some difficulty will arise if the opening is directed appreciably downstream, for then the suction pressure at the slot has a drag component. Experiments on relatively thin strut sections have shown no reduction in net drag. If air is blown rearward the boundary layer is accelerated and a thrust accompanies the reduction in drag.

In determining the effectiveness of the blowing in reducing the drag, the energy of the jet must be considered and an appropriate addition made to the measured drag. The jet reaction can be expressed as

$$T = C_{DS}\frac{\rho V^2}{2}A,$$

where A is the cross sectional area of the body normal to the wind, V is the relative wind velocity, and the coefficient C_{DS} is then of the same nature as the usual drag coefficient C_D. It can therefore be directly added to it. What is sought then is a reduction in the magnitude of the sum of C_D and C_{DS}.

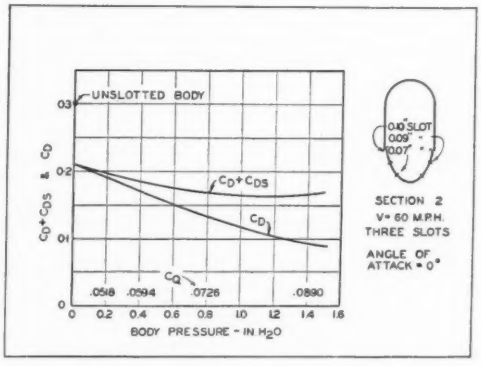


FIG. 1. Drag Curves for Section 2.

The quantity of fluid employed has a practical interest and can be given as

$$Q = C_Q A V$$

The coefficient of quantity C_Q is then non-dimensional.

The pressure within the body and the volume of discharge determines the energy employed in the jets, and so determines the coefficient C_{DS}.

Of the cylinders studied, the 5-inch elliptic end proved the most satisfactory from the standpoint of both bluntness and low drag. The location of the slots and their width are indicated on Fig. 1. There were three slots per side. The results are shown in the figure. The drag coefficient as measured on the balance is C_D while the inclusion of the drag coefficient C_{DS} to represent the thrust of the jets gives the curve marked $C_D + C_{DS}$. The drag of a smooth cylinder is represented for comparison and it is to be noted that there is about a 33 percent reduction in drag for atmospheric pressure within the body. For still higher pressures the drag drops to about 50 percent of the drag of the unslotted body. The quantity of air is relatively small as indicated by the C_Q values.

The above results are sufficiently encouraging that further research is being advanced on the blunter and finer sections and another body having a rear end of compound curvature is to be constructed for further experimentation.

W. LAURENCE LePAGE
Day & Zimmermann, Inc.

Rotative Wing Aircraft Possibilities. Rotating wing aircraft of four distinct classes were discussed, namely, (1) the Autogiro (articulated rotor blades); (2) the Gyroplane (feathered rotor blades); (3) the Cyclogiro; and (4) the Helicopter.

The summary might also include the Vertoplane, an effort to produce a convertible airplane by the release and autorotation of the special upper wing. The plane has been in the air as a biplane and as a windmill plane, although conversion in flight has not, to my knowledge, been accomplished.

The Autogiro. Unlike the fixed wing airplane, the L/D curve of the autogiro rotor reaches its maximum at the incidence of top speed. Parasite drag, flattens the L/D curve of the autogiro rotor so that its L/D ratio is approximately constant from climbing conditions to full speed flight. While the fixed wing airplane has its maximum L/D under climbing conditions and, in full speed is operating at distinctly reduced aerodynamic efficiency, the autogiro flies at $V_{max.}$ under conditions of maximum aerodynamic efficiency.

Due to the lower structural stresses in the rotor system than in the fixed structure of an airlpane wing, it is anticipated that lower design factors will prove practical in the case of rotating wing aircraft.

Because, under all conditions of flight in a properly designed autogiro, the incidence of the rotor system determines the attitude of the rest of the autogiro structure, it is possible to arrange the fixed wing, of proper design, such that it functions at its maximum L/D under the $V_{max.}$ conditions and consequently raises the overall L/D of the ship. For this and other reasons it is the writer's opinion that a properly designed small fixed wing is always advantageous in the autogiro, even in the new "direct control" types. The limit in top speed in the autogiro is determined by the stalling of the retreating blade elements, and this will always remain the limiting $V_{max.}$ condition.

The Gyroplane. The Gyroplane with feathering blades possesses many of the inherent advantages of the Autogiro. However, a higher disc loading is essential in order to insure high r.p.m. to reduce bending stresses in the individual blades. Since the large fixed wing in this type carries an appreciable percentage of the load, it is the fixed wing rather than the rotor system which controls the attitude of the machine in flight, and consequently the advantages of fixed wing $L/D_{max.}$ at $V_{max.}$ are not present.

The Cyclogiro. From theoretical considerations the Cyclogiro should possess good performance, especially in vertical and near-vertical climb. However, structural weight, aerodynamic resistance, and mechanical complexity limit practical possibilities.

The Helicopter. Extensive theoretical analyses indicate the extremely favorable vertical lift characteristics of power driven rotating blades. Failures in experimental developments to date have been caused primarily by inadequate solutions to the technical problems involved. However, a promising solution to power driven vertical flight is the Platt Vertigiro, which, in essentials, consists of a power driven Cierva articulated rotor, rotating about a tilting axis and with appropriately designed anti-torque surfaces operating in the rotor slipstream.

Conservative calculations point to almost phenomenal climb characteristics. High speed possibilities, by reason of the forward tilt of the power driven rotor axis, are equally promising and there are no normal propeller losses.

Because of the increasing forward inclination of the rotor axis in a power driven articulated system, the rolling moment decreases with increased velocity, while the reverse is true in the case of the Autogiro. Flapping, a distinct source of aerodynamic inefficiency, therefore decreases with increased velocity until, when the advancing blades are at zero lift incidence and the retreating blades at high incidence but almost zero relative velocity, the rolling moment is practically zero and blades instantaneously located at the fore and aft phase angles of the cycle carry the entire thrust load.

ALEXANDER KLEMIN
New York University

Ground Looping. Dr. Klemin pointed out that the subject was extremely complex as in addition to the usual aerodynamic factors, the ground reaction of the wheels had to be taken into account. The most likely occurrence for the ground loop was a dead-stick landing, when the rudder was blanketed and obtained no reinforcement from the propeller slipstream. Analysis indicated that it was quite possible to obtain a loop with right turn and tipping to the right or a loop with right turn and tipping to the left. One of the main factors in the occurrence of ground looping was

found to be the tail wheel. While the new style of putting the main wheels behind the center of gravity might be helpful in some types of landings, such an arrangement might introduce difficulties of its own. Equations of motion were set up in classical form. While the subject is by no means exhausted, the following practical rules were submitted for comment to designers wishing to avoid the occurrence of ground looping: wide tread, moderate dihedral, low center of gravity, restrained tail wheel, efficient vertical tail surfaces, and large moment of inertia about a vertical axis."

H. PETERS & C. G. ROSSBY
Massachusetts Institute of Technology

Some Comments on the Theory of Boundary Layer. The concept of boundary layer as introduced in fluid mechanics by Prandtl has been very fruitful in the interpretation of experimental data, particularly on fluid resistance. Our present knowledge of boundary layer is sufficiently advanced to permit the computation of frictional drag in the special case of plane surfaces moving parallel to the flow and over a wide range of Reynolds Numbers. On the other hand, the application of the boundary layer mechanics to many cases of practical interest is impossible because the behavior of the boundary layer cannot yet be quantitatively expressed as a function of certain important departures from planar flow, chief of which are the surface curvature and gradients of surface pressure which are commonly met with in engineering.

Especially fruitful was the introduction of the similarity concept of the turbulent flow pattern by von Kármán, which led to the determination of the mixing lengths $l = K(u'/u'')$ and the logarithmic velocity distribution. This distribution, of course, cannot hold true in the center of a pipe line or at the outer part of the boundary layer along a plate, since it would require the mixing length l to become equal to 0. Nikuradse's measurements in pipe lines show that l reaches a finite value $l = cd$ with $c = 0.07$ and d the diameter of the pipe line. c decreases slightly with the Reynolds Number.

The same value for c was obtained by Tollmien in the mixing zone of a two dimensional jet with $l = 0.068\ b$ where b is the width of the mixing zone. For a circular jet the result was $l = 0.073(d/2)$ with d the diameter. It therefore seems possible to write the mixing lengths, in cases where U'' approaches 0, as $l = (cd/n)$, with n a simple number and the numerical value for the factor c approaching 0.07.

Rossby recently found for the atmosphere the maximum value of $l = (0.065H/\sqrt{2})$ where H represents the thickness of the layer of variable stress (about 90 percent of the total turbulent layer).

These numerical relations seem to be more than a mere coincidence. It is, therefore, suggested that it may be possible to determine the velocity distribution in the boundary layer with the aid of certain assumptions. Next to the wall, assume a layer of constant stress within which the mixing length increases proportionally to the normal distance from the wall; further out assume a layer of rapidly diminishing stress within which the mixing length is independent of y but approximately proportional to the distance from the leading edge. At the transition level between those two layers continuity is required in velocity, stress, and mixing length.

This method has been applied to a few simple problems and seems to promise satisfactory results.

JOSEPH S. NEWELL
Massachusetts Institute of Technology

The Design of Stiffeners. In an attempt to rationalize the design of channel stiffeners and similar sections studies were made on the applicability of formulas for predicting loads on flat sheets having different conditions of edge support. The studies showed that the crippling strength of a short channel column, L/ρ about 20, may be predicted approximately by considering the back of the channel to behave as a flat plate having all four edges simply supported, while the legs are taken as two flat plates, each having three simply-supported edges and one free edge.

The crippling stresses determined by summing up the loads predicted for back and legs were found to be in good agreement with tests on sections made at the Massachusetts Institute of Technology and by Roy Miller at McCook Field. By substituting the average stress at the crippling load for the yield point in the Johnson parabolic formula for columns, it was found that a good agreement could be obtained with test data for channels in the short column range. For long channels the Euler column formula is satisfactory.

Investigations of other shapes of stiffeners, lipped channels, zees, etc. all combinations of flat surface elements, show good agreement between crippling loads obtained from tests and those predicted by use of the flat plate formulas. Sufficient data have not been obtained to determine whether the Johnson parabola or some other formula gives the most satisfactory results for such members in the "short" column range, but from the few data in hand the Johnson parabola appears to be in fair agreement. In good enough accord, in fact, to indicate that the method of rationalizing stiffener design should be investigated further on sections of other shapes and materials.

TH. THEODORSEN
National Advisory Committee for Aeronautics

Vibration of Propeller and Engine Crankshaft. A recent increase in the number of propeller failures has focussed the attention on this problem. Propeller failures may apparently be classified in two fairly distinct groups as shank failures and tip failures. It has been conclusively proven that the former are caused by the engine-crankshaft unit, and are not directly due to any weakness or faulty design of the propeller. The propeller-engine combination forms a mechanical system capable of torsional vibrations. Because

of the relative concentration of the inertia in the propeller and in the engine, there is only *one* critical response frequency. This frequency is found to be located in the neighborhood of 10–13,000 vibrations per minute for modern one and two-row radial engines. This frequency may coincide with the frequency of the explosions in the engine. In fact, it was found to coincide exactly in a certain case in which trouble with shank failure had been experienced.

In regard to tip failures, the propeller itself exhibits several modes of critical response. The fundamental is usually located near 2,000 cycles per minute, the second mode at about 6,000, and the third at 10–12,000. These frequencies may easily be measured on a stationary propeller. They are considerably increased by the effect of centrifugal force. A new method developed has been the N.A.C.A. laboratory to obtain this effect accurately by simple means. The method employs an affine model of the propeller to be investigated, obtained by reducing the cross section say ten times but retaining the length. In other words, it is a one-tenth size model stretched to full size along the blades. This model is run at one-tenth revolution speed of the original. It can be shown that under these circumstances all frequencies are one-tenth of those of the original propeller. Each blade is enclosed in a thin metal tube to prevent air forces influencing the results. While revolving, the propeller is subjected to a vibrating force. At each critical frequency the propeller blades hit the protecting tube, which serves as an audible indicator. As many as five modes are recorded. Results of experimental tests show good agreement with available results by Liebers for the fundamental and theoretical calculations by Hohenemser for the second and third mode.

R. P. HARRINGTON
Brooklyn Polytechnic Institute

The Flow in the Wake of an Ellipsoid of Revolution. Some of the results of his recent research on the nature of the flow around an ellipsoid of revolution were discussed. Flow on the surface was indicated by lampblack and kerosene traces on the model and the motion in the wake investigated by a special yawmeter. It was shown that the flow on the rear section of the leeward side deviates from that expected in the light of potential theory since it "feathers" outward from the pitching plane toward the minimum pressure region. The flow about 0.7 cm from the surface in the same region "feathers" inward as was indicated by an exploring thread. Therefore a surface of discontinuity apparently exists over this section a short distance from the surface of the ellipsoid where the flow is in such directions as to generate vorticity in the direction indicated by wake measurements. The traces show that the flow on the windward surface of the ellipsoid is similar to that expected in potential flow.

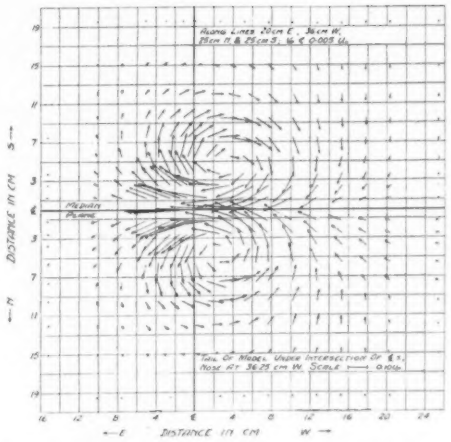


FIG. 1. Induced velocity V_p in plane normal to U_0 located 20 cm. behind ellipsoid at $\alpha = 21.5°$. $U_0 = 22.3$ *M/s.*

Fig. 1 indicates the vector field of the induced velocities in the wake at a distance of 20 cm. behind the model at a velocity of the undisturbed flow equal to 22.3 meters per second and at an angle of attack of 21.5°. The model was 99 cm. long and had a fineness ratio of 6.0. The configuration of the velocities approximates two vortex cores. Measurements in another plane 9.6 cm. astern indicate that the cores are moving downward and that the vorticity had evidently originated on the rear leeward surface of the ellipsoid.

The static pressure and the vorticity distribution in the planes of the wake was discussed. Lift calculations from the vorticity in the wake, assuming a line lifting vortex, are in close agreement with the measured values giving a value of $C_L = 0.168$ as compared with $C_L = 0.178$ from the force measurements.

A complete paper covering the entire scope of the investigation will be presented in the next publication of the Daniel Guggenheim Airship Institute.

Prof. C. Fayette Taylor and Dr. Graham Edgar acted as chairmen. Abstracts of some of the material presented are given below, but the report of the Wright Field tests with 100 octane fuel by Lieut. F. D. Klein is printed in full, in view of the possible significance of the data.

Arthur Nutt, in discussing aircraft engine trends, explained that European engines gain their higher performance by the use of large cubic displacement and overspeeding at the expense of reliability through the use of lenient endurance tests. Trends in the United States must be towards larger engines and increased supercharging.

C. S. DRAPER

Massachusetts Institute of Technology

The Physical Aspects of Detonation. Detonation phenomena which accompany the use of ordinary fuels in Otto cycle engines are of great importance since they impose limitations in design. Any effect upon the engine must be of a physical nature, so a quantitative knowledge of the physical aspects of detonation will be of assistance in treating the problem. The present report outlines the methods and results of a detonation study which has been carried out at the Massachusetts Institute of Technology under the supervision of Professor C. F. Taylor.

The sound effects which accompany detonation indicate definitely that sudden pressure changes within the cylinder are involved. Since the energy content of the cylinder charge is insufficient to produce general cylinder pressures much higher than those existing during normal operation, any sudden pressure rise must be localized within some part of the charge. Certainly a sudden pressure rise will set up pressure waves within the cylinder, just as a firecracker exploded in a closed drum will excite sound waves within the drum. These pressure waves will form part of a resonant frequency system whose behavior should follow the predictions of sound theory, if the assumptions of that theory are valid for the case of Detonation.

Sound theory gives a relation between frequency, wave length and sound velocity in a continuous medium. For a circular cylinder with flat ends, the wave lengths corresponding to the various resonant frequency modes may be calculated. Fortunately the lower modes have widely different frequencies so it is possible to identify the mode which is excited in a given case. Sound velocity in a gaseous medium may be calculated from the relation

$$c = \sqrt{\frac{\gamma P_0}{\rho_0}} = \text{velocity of sound},$$

$$\gamma = \frac{\text{Specific heat at constant pressure}}{\text{Specific heat at constant volume}},$$

P_0 = equilibrium pressure,

ρ_0 = equilibrium density.

For the case of an engine in operation, the wave length may be calculated from cylinder dimensions, ρ_0 may be estimated from a knowledge of air flow through the engine, while P_0 may be measured with an engine indicator. From these data the detonation frequency to be expected at any point of the engine cycle may be computed. Direct measurements of detonation frequencies made with the aid of a specially constructed indicator agree with the corresponding calculated frequencies within the experimental error.

The material outlined above has been discussed at greater length by the writer in N.A.C.A. Technical Report No. 493.

HUGH L. DRYDEN

National Bureau of Standards

An Experimental Attack on the Propeller Vibration Problem. An investigation of the vibration of aircraft propeller blades conducted at the Bureau of Standards under the direction of Dr. L. B. Tuckerman and the author was described. The ultimate aim of the study is a diagnosis of the causes of the failure of propellers in flight. The evidence available points to resonant vibrations of the propeller blade itself or of the propeller-crankshaft system as the source of alternating stresses of sufficient magnitude to produce the observed failures. The following line of attack has been outlined and in part completed:

(1) Develop a method for applying periodic impulses of controllable frequency and amplitude to non-rotating propeller blades so as to set up resonant vibrations of sufficient amplitude to cause failure, if possible.

(2) Develop a method for measuring the stresses set up in the vibrating blade and if possible obtain values at the points of failure for the stresses just preceding failure.

(3) Extend these methods to propeller blades in rotation.

The method of vibrating non-rotating propeller blades has been briefly described in Research Paper 556 of the National Bureau of Standards.

The measurement of stress distribution in non-rotating propeller blades will be described in full in Research Paper 764 which will appear in the February number of the Journal of Research of the National Bureau of Standards. The results were presented to the Institute of Aeronautical Sciences in the form of lantern slides.

A demonstration model was exhibited to illustrate the type of equipment developed for vibrating non-rotating propellers and the possibility of vibrating rotating propellers by the same means. The model included a small motor-generator set which could be operated at speeds to give alternating current of any desired frequency between certain limits, and an ordinary d.c. motor. The motor was

mounted so that the housing could be rotated in bearings by belt drive from another motor while at the same time the shaft, on which the propeller was mounted, could rotate in bearings in the housing. The field and armature windings were connected respectively to a d.c. source and to the a.c. output of the motor-generator set through slip-rings. The motor thus served not only as a source of alternating torque, but also as an electromagnetic clutch to rotate the propeller. The blades were vibrated by adjusting the frequency of the alternating current supplied to the armature to equal one of the natural frequencies of the model-propeller blades.

In a large scale installation, it would probably not be practical to use the vibrating motor as a clutch, and it would probably be desirable to drive the propeller shaft through a flexible spring-coupling, so that the propeller could be vibrated without the inertia load of the armature of the driving motor.

Reference was made to the work in progress on the development of a suitable propeller-vibration indicator which might be used to locate dangerous engine speeds in flight. An early design of such an instrument is described in Research Paper 678 of the National Bureau of Standards.

GRAHAM EDGAR
Ethyl Gasoline Corporation

Aircraft Fuels of the Future. The role of a prophet has always been a thankless and somewhat dangerous one, and in venturing to assume such a role, the writer is fully aware that in all probability he will be proven to be entirely wrong in his prophecies.

Aircraft fuels of today are almost entirely made up of straight-run gasolines. Their difference in most properties, such as volatility, sulfur, etc., are relatively unimportant and their classification in the trade is based upon their anti-knock value. Outside of the small amount of unclassified gasoline sold today, three classes are available, namely, 73, 80 and 87 octane number, the two latter classes invariably containing tetraethyl lead. The proportion of 87 octane number gasoline is increasing rapidly, with the increased use of high duty transport engines requiring this fuel. (By the Army Air Corps Methods of test, this fuel usually rates around 92 nominal octane number.)

The highest anti-knock fuels of today are made by distilling selected crude oils known to give gasolines of high natural anti-knock value, and then adding tetraethyl lead. This process appears to have reached an approximate limit around 87 octane number.

Cracking processes, in which the higher boiling constituents of crude oil are broken down into material boiling in the gasoline range, appear today to offer no prospect of producing an aviation gasoline better than 87 octane number, either with or without the addition of tetraethyl lead.

Hydrogenation has been said to be capable of producing gasoline of very high octane number, but there is conflicting information on this point, and it cannot be said with confidence that this process can or will produce satisfactory aviation gasoline of anti-knoch value substantially higher than 87.

How then can gasoline of 100 octane number and above be made?

The writer suggests that it can be most easily made by breaking down the petroleum molecules into small bits, as it were, and then rebuilding them into fuels of high anti-knock value. On other words, by synthesis.

The breaking down process occurs today accompanying every cracking operation. A portion of the oil is broken down into gaseous material, containing one, two, three or four atoms of carbon per molecule. It is here that I believe we may find the starting point for the aircraft fuel of the future.

Given our small molecule, and assuming that we can build it up in various ways, what chemical type of fuel do we wish to form from it. Here, fortunately, considerable data is available, as a result of experimentation upon pure hydrocarbons.

Three classes of hydrocarbon are known which possess extremely high anti-knock value. These are (1), condensed or branched chain paraffins. Iso-octane (2,2,4-trimethyl-pentane) is an example of this class, and others are known of even higher anti-knock value; (2), branched chain olefins, of which di-isobutylene is an example; and (3), certain aromatic hydrocarbons, preferably more complex than benzene itself.

Of these classes, it would appear that for high performance aircraft fuel, the condensed paraffins offer the greatest possibilities, as they retain their high anti-knock value under almost all conditions; they are chemically stable, and they have the highest heat of combustion per pound.

At the present time more is known about the synthesis and full-scale engine use of iso-octane than of any of the other fuels suggested above.

It has been eight years since our own laboratory first described the high anti-knock value of this material and proposed its use as a primary standard for anti-knock determinations. Within the last two years, substantial quantities of it have been prepared in reasonable purity by more than one oil refiner, starting with the isobutylene of refinery gases. We are fortunate in being able, in the next paper, to see one of the possibilities of this fuel in actual aircraft use.

It should be pointed out that, of necessity, synthetic fuels will be substantially more expensive than those produced by simple distillation methods. They will, therefore, only come into wide commercial use if their advantages in the way of power production possibilities, are great enough to outweigh their extra cost. In the interest of economy, it is probable that any such fuel will be used as a blending agent, being blended with the best available gasoline, and also probably with conventional anti-knock agents rather than in the pure state.

H. L. CARPENTER
Wright Field

Cold Temperature Starting of Air Corps Engines. Considerable trouble has been experienced in starting airplane engines of 500 H.P. and over at sub-zero temperatures. No data were available regarding the torque required, the number of turns necessary, or the rate at which the engine should be turned, in order to produce reasonably good starting efficiency, from which the starter manufacturer could develop a heavy duty starter for this work. Accordingly, an investigation was made at the Material Division, Wright Field, Dayton, Ohio, using a cold chamber and an Air Corps type GIV-1570-F engine.

Tests were conducted to determine the torque, r.p.m. and the number of revolutions required to start this engine at various temperatures ranging from plus 15°F. to minus 20°F. Torque measurements were also taken using grades 98.77 and 55 sec. oils (Saybolt test at 210°F.) in the engine at these temperatures. All tests were recorded in Fahrenheit degrees. From these tests it was determined that:

(a) At temperatures down to and including plus 5°F., the engine can be started on the first revolution, when being cranked at a minimum speed of 70 r.p.m. At temperatures lower than plus 5°F., it is necessary to turn the engine from one to five revolutions at the same average rate.

(b) Engine oil must be used which has a viscosity low enough to allow this to be accomplished. (Oil coolers should be used if necessary to keep the oil temperature down after the engine has been started.)

(c) The engine must be primed at the engine intake manifold directly over the intake valves, and the priming fuel used must be broken up by the priming jets into as fine a spray as possible.

(d) The engine carburetor must be designed so that the volume of fuel entering the engine can be adjusted to full rich for starting, and as the engine warms up, it may be "leaned" down so as not to overload the engine.

(e) The ignition must be installed so that it may be retarded to prevent back firing at low cranking speeds, and shall give positive spark at the proper time. Battery ignition was found to be better for starting than magneto ignition.

(f) The torque required to turn the engine over must be approximately 300 ft. lbs. lower than that of the starter clutch setting, in order that there is enough reserve energy in the starter to turn the engine for one or more revolutions. The starter clutch shall never be set over a maximum of 900 ft. lbs. breakaway torque, as higher torque will cause failure of engine and starter parts.

The torque required to turn the engine over at 10 r.p.m. when using grade 98 oil, reached a value of 410 ft. lbs. at plus 10°F. while at the same speed and with grade 55 oil in the engine the temperature dropped as low as minus 15°F. before the same value was reached. Torque readings taken with grade 77 oil in the engine and at minus 5°F. showed the torque to reach a value of 410 ft. lbs. at 30 r.p.m., 430 ft. lbs. at 40 r.p.m., 450 ft. lbs. at 50 r.p.m., 460 ft. lbs. at 60 r.p.m., and 480 ft. lbs. at 70 r.p.m.

Larger h.p. engines are being developed and the engine manufacturers will have to take into consideration the starting and running of these engines at low temperatures. The present engines will fire while being turned over with the present starters but the explosions are so weak that the engine can not be kept running.

Book Reviews

The Internal Combustion Engine, Vol. II, The Aero Engine, by D. R. Pye; Oxford University Press, England, 1934, 398 pages; ill., $7.00.

This is the second volume in the series so ably initiated by "The Internal Combustion Engine" by the same author (cf. Mechanical Engineering, January 1933, p. 67). Mr. Pye's long experience in the field of aircraft engines, together with his scholarly approach, result, as would be expected, in a thoroughly sound, authoritative and readable volume. W. S. Farren, in Chapter II, contributes a valuable analysis of the relationship between engine, propeller and airplane.

The treatment presupposes considerable knowledge in the field of internal combustion engines in general, and of the aeronautical engine in particular. The subject matter is mostly confined to performance problems and to questions of cooling, lubrication, carburetion, supercharging and to the possibilities and limitations of the two-stroke cycle. Incidentally, the discussion of the latter topic is quite the best this reviewer has seen.

All topics are handled broadly, and descriptive matter is studiously avoided, except where it illustrates principles. This policy constitutes both the strength and weakness of the work, for while it makes it valuable outside the aeronautical field, it necessarily excludes much specific information which might be of direct help to the designer of aircraft engines.

Evidently, however, the book is not oriented toward design, for mechanical and structural problems are not considered, except incidentally. It is to be hoped that a subsequent volume in the series will cover this field.

C. F. TAYLOR.

Third Annual Dinner

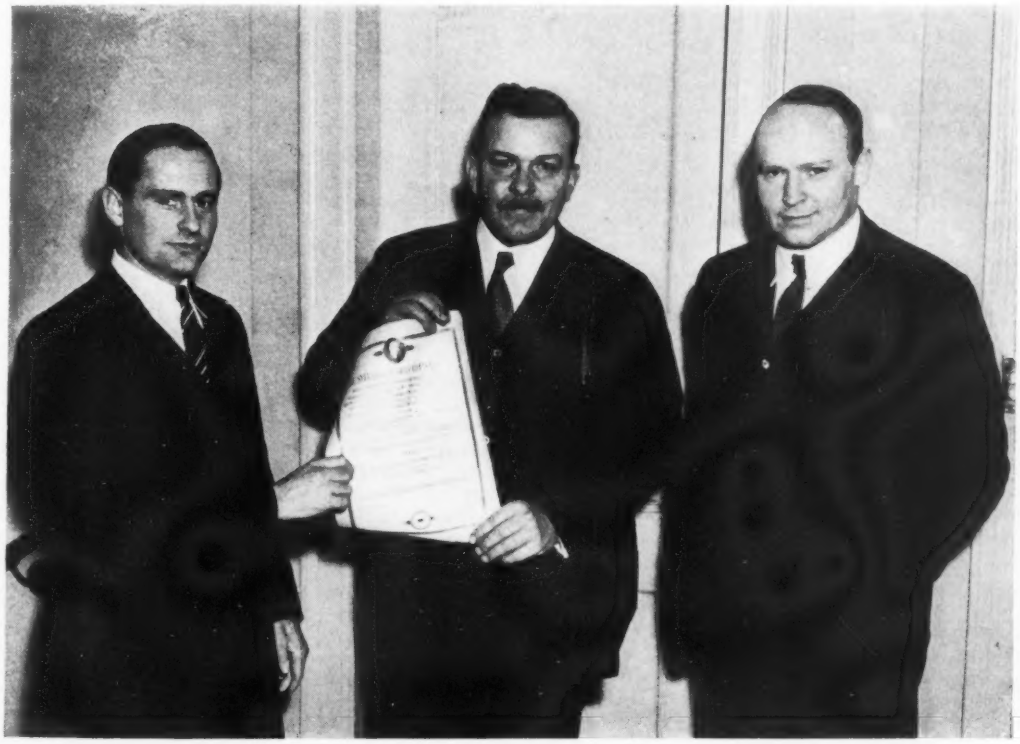
Nearly three hundred members and guests attended the Annual Dinner of the Institute, which was held at the Faculty Club of Columbia University on January 30, 1935. Mr. Charles L. Lawrance acted as toastmaster.

An amusing guessing contest, based on a scientific dinner menu, provided a unique feature of the dinner. A beautiful (*sic*) silver cup was offered to the best guesser of the different foods served. Items were not listed in the order of serving. The eleven items listed were as follows:

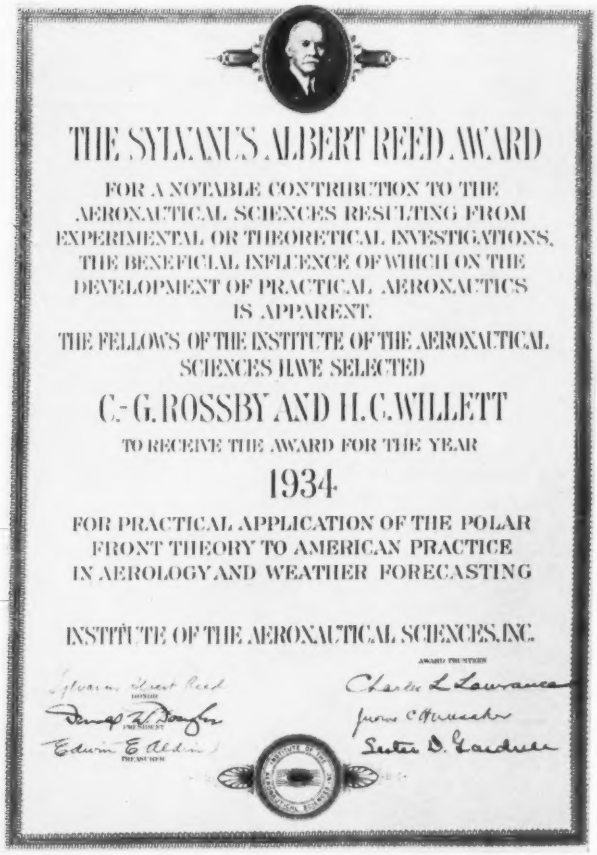
(1) Static Disturbance; (2) O—O; (3) Tropical Payload; (4) Ellipsoids of Revolution; (5) Us; (6) Humidity of 100 at 31°F.; (7) Crankcase dregs; (8) ... .—.—.; (9) Pancake Landing; (10) Tail skid decorations; (11) Inherent Stability.

After coffee had been served the slips were collected by Messrs. Wilford and de Florez. It was found that two persons had practically perfect scores. To determine the winner, the two persons with the highest scores, Dr. von Kármán and Mr. Beisel, matched coins, and Mr. Rex Beisel was declared the winner. Mr. Lawrance presented the cup. The correct answers were: (1) Celery; (2) Pea soup; (3) Fruit cup; (4) Olives; (5) Nuts; (6) Orange ice; (7) Coffee; (8) String potatoes; (9) Squash; (10) Escarole salad; (11) Roast beef.

Donald W. Douglas, the newly elected President, was introduced by Mr. Lawrance. Mr. Douglas thanked the members for the honor that had come to him in his selection for the



President Charles L. Lawrance (center) presenting the Reed Award Certificate to Dr. H. C. Willett (left) and Professor C.-G. Rossby (right).



THE SYLVANUS ALBERT REED AWARD

FOR A NOTABLE CONTRIBUTION TO THE AERONAUTICAL SCIENCES RESULTING FROM EXPERIMENTAL OR THEORETICAL INVESTIGATIONS, THE BENEFICIAL INFLUENCE OF WHICH ON THE DEVELOPMENT OF PRACTICAL AERONAUTICS IS APPARENT.

THE FELLOWS OF THE INSTITUTE OF THE AERONAUTICAL SCIENCES HAVE SELECTED

C.-G. ROSSBY AND H.C. WILLETT

TO RECEIVE THE AWARD FOR THE YEAR

1934

FOR PRACTICAL APPLICATION OF THE POLAR FRONT THEORY TO AMERICAN PRACTICE IN AEROLOGY AND WEATHER FORECASTING

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

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presidency. To succeed Dr. Hunsaker and Mr. Lawrance was a distinction he appreciated. He stated his belief that the selection of a representative from the Pacific Coast indicated the appreciation of the members of the widespread interest in the Institute work shown by that section, and assured the membership that he would do all he could to assist the Institute to continue to progress as it had during its first two years.

Before presenting the "Sylvanus Albert Reed Award," Mr. Lawrance asked Lester D. Gardner to tell of the founding of the Award by Dr. S. A. Reed, a Fellow of the Institute. Major Gardner said:

The Council of the Institute considered the possibility of securing awards for notable achievements in aeronautics which would not encroach on the fields covered by existing medals, trophies or prizes. Two requirements appeared to be essential. The award should bear the name of a person distinguished for his aeronautical work and should be endowed so that a cash prize could be given. The proposal was presented to Dr. S. A. Reed and he immediately agreed to establish the award. He agreed to have a certificate prepared and provided $250 a year to be given to the recipients and endow the award with a bequest of $10,000. Dr. Reed has all the qualification that the Council desired. He is a graduate of Columbia University, having received five degrees there including those of Doctor of Philosophy and Science. He later studied in the physical laboratories of Berlin and Wurzburg. He developed the duraluminum airplane propeller that has largely supplanted wooden propellers. For this he received the Collier

Trophy in 1925. Dr. Reed has asked J. C. Hunsaker, Charles L. Lawrance and Lester D. Gardner to act as trustees of the Award and has stipulated that any funds must be kept invested in Government Securities. In case the Institute dissolved the fund is to be turned over to the National Academy of Sciences. When it was proposed to name the Award, Dr. Reed hesitated to have his name used, but after consideration he agreed, as his direct ancestor, Captain Sylvanus Reed, for whom he was named, fought at Bunker Hill on the staff of Colonel Sullivan of Newport, and thereafter during the entire Revolution. For this reason he agreed to have the Award carry the name it does.

Mr. Lawrance then asked Dr. J. C. Hunsaker to describe the work of the recipients of the Award.

Dr. Hunsaker discussed the action of the Fellows in selecting Prof. Rossby and Dr. Willett to be the first recipients of the Reed Award in recognition of their joint contribution to aerological science and to practical forecasting. He explained how the fortunate collaboration of these two men came about with their entirely different but complementary backgrounds. Prof. Rossby graduated from Stockholm University and was trained in the new Norwegian polar front theory under its originator, Prof. Bjerknes, at Bergen. He was brought to this country by the Guggenheim Fund, worked in the U. S. Weather Bureau and on the California Model Airway, and in 1928 came to the Massachusetts Institute of Technology to establish a graduate course in modern meteorology. Prof. Rossby's field is dynamic Meteorology, the thermodynamics of the air and its great mass movements.

He was joined in 1929 by Dr. Willett, a synoptic meteorologist trained in the analysis of the weather situation of the moment and in forecasting its future development. Dr. Willett had graduated from Princeton and had taken his doctorate in Physics at George Washington University while working in the Weather Bureau. In addition he had spent a period in residence at Bergen studying under the Norwegian meteorologists.

The collaboration between Rossby and Willett, one dynamic and the other synoptic in approach, has proved most fruitful. Methods for identification of American air masses have been developed as well as methods and instruments for the practical use of airplanes for sounding the air masses to high altitude. For a number of years a daily analysis of the American weather map and a forecast have been prepared using the new methods and data. As a result, the general idea of air mass analysis, originated in Norway, has been adapted, developed and applied to American weather, together with a suitable instrumental technique.

It is singularly appropriate that the Reed Award be made to these two members who have done so much to advance the aeronautical Sciences, and the practical value of whose work has come to be so generally recognized.

The certificates were then presented to Professor Rossby and Dr. Willett by Mr. Lawrance, together with checks for $125 each. Professor Rossby accepted the Award for himself and his associate and expressed their great appreciation of the honor. He pointed out that while the award was primarily for aeronautical work, the presentation of the award by aviation specialists to two meteorologists would also assist in bringing to public attention the recent advances made in the science of meteorology.

Mr. Eugene L. Vidal, Director of Air Commerce, spoke on the "Technical Problems of the Bureau of Air Commerce." A summary of his remarks follows.

No previous year has shown more promise for the development of aviation in all its phases than 1935. Contemplated legislation as proposed in the report of the Federal Aviation Commission, the acceleration of military aviation programs abroad, plans of our domestic and foreign airlines for both expansion and extension, and the recent development of planes and airports for the private owner will result in unparalleled commercial aviation progress.

The Institute of Aeronautical Sciences is to be congratulated on its work of the past year and particularly for the success of these meetings. Certainly this is the greatest gathering of aeronautical scientists and engineers to date.

The aviation art can only be developed from contributions of technical individuals such as are gathered here, and so after all, its progress is to a great extent in your hands.

The dinner guests were then privileged to see three series of motion pictures. The first was presented by Eastman N. Jacobs of the National Advisory Committee for Aeronautics.

EASTMAN N. JACOBS
National Advisory Committee for Aeronautics

Air-Flow Pictures Shown at the Third Annual Dinner. N.A.C.A. Technical Film No. 2, entitled "The Fundamental Nature of Air Flow and Flow Separation," by Eastman N. Jacobs and Ira H. Abbott, was displayed publicly for the first time before the Institute of the Aeronautical Sciences following the third annual dinner at the Faculty Club, Columbia University. (Copies of this film will be available for loan from the National Advisory Committee for Aeronautics, Washington, D. C.)

The picture deals in rather an elementary way mainly with the well-known phenomenon of air-flow separation. When separation occurs, the main flow with its boundary layer runs over an accumulated mass of dead air instead of over the actual body surface, usually producing undesirable effects such as the stall of airplane wings. Although

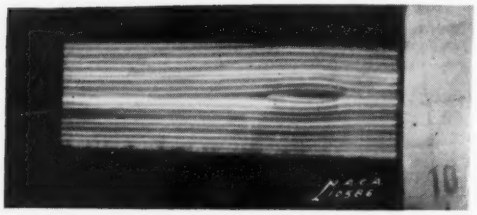

FIG. 1. Small-scale flow about symmetrical (N. A. C. A. 0012) section at zero angle of attack.

the general nature of the conditions leading to separation has been appreciated for some time, having been treated by Prandtl, the subject has not been completely treated quantitatively. Such a treatment, although desirable, is not necessary. For many purposes a clear mental picture serves nearly as well. These moving pictures of air flows made visible by smoke streamers as shown in Fig. 1, are intended to aid in clarifying such mental pictures.

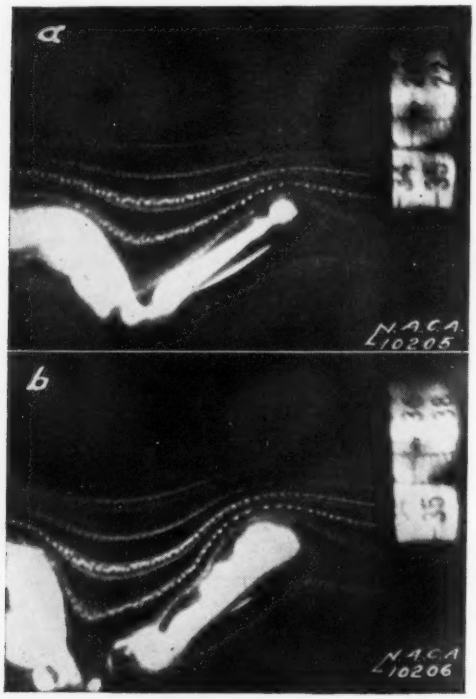

FIG. 2. Flow about N. A. C. A. 0012 airfoil.
(a) Separation developing just after a suddenly increased angle of attack.
(b) The further development of separation 0.16 second later.

One feature of the flows must be kept constantly in mind in applying to flight problems the concepts that may be derived from the pictures. The flows photographed in the N.A.C.A. smoke-flow equipment are at relatively low Reynolds Numbers as compared with the flows usually dealt with in flight. Allowances must therefore be made for

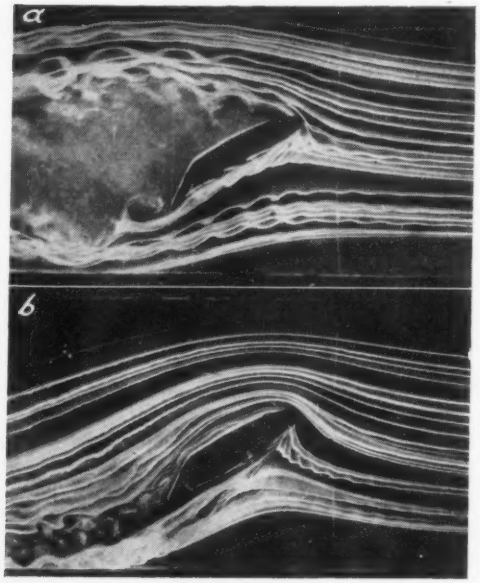

FIG. 3. N. A. C. A. 2415 airfoil with trailing-edge flap.
(a) Showing separation and stall without boundary-layer control.
(b) Flow with boundary-layer control by suction.

the relatively larger viscous forces, the thicker boundary layers, and the later development of turbulence. Owing to such differences, it must be appreciated that the pictures are of value mainly as a means of studying the fundamental character of flows.

The pictures nevertheless are of value in showing actual flows under the conditions of the experiment and showing how the flows are affected by various changes. For example, the pictures give information as to whether or not the laminar separation point moves as the Reynolds Number is changed. Separation is shown in "slow motion" as it develops when the flow starts from rest on the N.A.C.A. 0012 airfoil section at zero angle of attack. Marked separation is shown to develop at a Reynolds Number of approximately 20,000 but, as predicted,[1] separation was shown to fail to develop under similar con-

[1] Eastman N. Jacobs, *Aerodynamics of Wing Sections for Airplanes*, S.A.E. Journal, March, 1934.

ditions at a lower Reynolds Number obtained by employing smoke-flow equipment one-sixth of the scale of the usual equipment. This experiment was of particular interest because of contrary theories.[2]

The picture goes on to show how separation develops under various conditions, as, for example, in Fig. 2, after the angle of attack of an airfoil is suddenly increased, and finally considers various means for the control of separation. The picture concludes by demonstrating the marked effectiveness of boundary-layer control by suction as applied to the N.A.C.A. 2415 airfoil with trailing-edge flap. (See Fig. 3.)

[2] See discussion of preceding paper by Clark B. Millikan. S.A.E. Journal, June, 1934.

The second picture, entitled "The use of Animated Pictures for Weather Studies," was presented by Dr. Irving P. Krick of the California Institute of Technology.

IRVING P. KRICK
California Institute of Technology

The Use of Animated Pictures for Weather Studies. To clarify discussions of the Norwegian methods of weather analysis, animated pictures give a method of showing the physical nature of weather phenomena by the interaction of various types of air shown both in horizontal and vertical cross-section. The situation chosen for illustration occurred during the period December 30, 1933 to January 2, 1934, in the vicinity of Los Angeles and resulted in very heavy rains in the area. The maps for this period were analyzed and through interpolation several hundred intermediate charts constructed, so that the movements of the frontal systems involved became continuous when photographed on a motion picture film, one map at a time. The correct animation of the film, and in fact the entire technique needed in order to produce a satisfactory film of this type, were made possible through the cooperation of the Walt Disney Studio in Hollywood.

The peculiar nature of the storm is shown quite clearly through the continuity which the film provides. Two distinct types of precipitation occurred in the Los Angeles region during the storm, namely a light steady type in the initial phases of the development, and later a heavy steady type, the transition from the former to the latter being a very rapid one. The various air mass interactions which give the physical explanation of these phenomena are shown in the film through the use of synchronized horizontal and vertical projections.

The third technical film was described by Mr. A. M. Rothrock of the National Advisory Committe for Aeronautics.

A. M. ROTHROCK
National Advisory Committee for Aeronautics

Effect of Air-Fuel Ratio on Combustion in a High-Speed Compression-Ignition Engine. High-speed motion pictures at the rate of 2,500 frames per second were taken of the fuel-spray formation and combustion in the N.A.C.A. combustion apparatus operating as a compression-ignition engine. This apparatus consists of a single-cylinder test engine constructed with a combustion chamber having glass windows 2.5 inches in diameter through which the whole injection and combustion process can be observed. In operating the engine a single charge of fuel is injected. The air-fuel ratio was varied from 10 to 365. The normal operating range of a diesel engine is 17 to 80. The motion pictures showed the fuel sprays entering the combustion chamber and penetrating the highly compressed and heated air. The ignition of the sprays took place in the spray envelope and occurred simultaneously at several different places in the chamber. In 5 crankshaft degrees (the engine speed was 1,500 r.p.m.) the flame reached its greatest spread. As the fuel quantity was decreased definite stratification of the fuel charge became evident. At the smaller fuel quantities the flame did not fill the combustion chamber and the area covered by the flame was clearly defined. The interpretation of the spray and flame pictures was assisted by the addition of indicator cards taken under the same conditions. The indicator cards as shown in the motion picture were animated to the same relative time scale as the spray and flame pictures. The resultant effect was that which would be obtained if the observer were able to increase his speed of vision 200 times

Third Annual Meeting of the Institute of the Aeronautical Sciences

THE Third Annual Meeting of the Institute of the Aeronautical Sciences, Inc., was held in the Physics Building at Columbia University, New York City, on January 30, 1935. Charles L. Lawrance, President of the Institute, presided over the meeting and Major Lester D. Gardner acted as Secretary.

After the minutes of the previous Annual Meeting had been read and approved, the President read his Annual Report.

The President's Annual Report

THE second fiscal year of the Institute ended on September 30, 1934. So that there may be ample time for the financial reports and the auditing of accounts to be completed, your officers make their reports in January, four months later.

The second year of any organization is always critical. During the first year of any group effort, many persons are willing to associate themselves with a new project. They join with the hope that the assurances of the organizers will be realized. About the second year they can determine how successfully the original plans have materialized.

The continuous growth in membership has been the best indication of the fundamental soundness of the basic principles underlying the Institute. This increase has come naturally without any effort to induce anyone to join.

Another, and equally important element in appraising the value of any organization is the payment of dues. I am sure that you will be gratified when you hear the Treasurer's report.

The work of the Institute may be divided roughly into three parts:

1. Publishing
2. Professional
3. Executive and clerical.

The Journal. Any group such as that comprising the membership of the Institute is judged principally by the character of its official publications. The Institute started its publishing work modestly by issuing a bound volume of the Proceedings of its First Annual Meeting. In January 1934, the first issue of the *Journal* appeared. During 1934 it was issued as a Quarterly. The favorable impression created by the first four issues caused the Council to increase the number of issues to six a year. The editorial contents have been of a uniformly high standard and the Institute is indebted to Dr. Hunsaker for the editorial direction which has required much time and labor. The American Institute of Physics placed at our disposal its excellent facilities and I wish to express publicly our appreciation for the cooperation which we have received. The cost of starting any publication is always much more than is generally realized. If it had not been for the support given by many companies engaged in aeronautical activities, it would not have been possible to issue the *Journal* and send it to members. I wish to thank those companies which have advertised and hope that our members will also regard the support as a contribution to the work of the Institute as well as ordinary advertising. To those who have contributed papers, we are also greatly indebted. All papers have been submitted as a contribution to the advancement of the aeronautical sciences.

The Reed Award. The second function of the Institute is to advance the standing of the aeronautical profession. Perhaps the most encouraging happening of the past year in this effort has been the establishment by Dr. S. A. Reed of the "Sylvanus Albert Reed Award," to be given annually for "a notable contribution to the aeronautical sciences." The Council passed the following resolution and directed that it be read at the Annual Meeting:

"*Resolved*, that the Council of the Institute of the Aeronautical Sciences, Inc., express to Dr. S. A. Reed the formal appreciation of the Institute for his generosity in providing the 'Sylvanus Albert Reed Award' for the advancement of the Aeronautical Sciences."

Dr. Reed has had a handsome certificate prepared and is giving with it $250, annually, to the recipient. He has further agreed to endow the Award with a bequest of $10,000. Such confidence in the future growth and usefulness of the Institute from one of our Fellows is of great significance. The Award will give recognition to those engaged in the advancement of the aeronautical sciences, and encourage the application to practice of theoretical and experimental investigation. I suggest a rising vote of thanks from the entire membership in appreciation of Dr. Reed's generosity.

Federal Aviation Commission. Another important professional service was the appearance of representatives of the Institute before the Federal Aviation Commission. This is the first time to my knowledge that aeronautical engineers and scientists, as such, have had an opportunity to present to any governmental agency a statement on national aviation policy. I feel that this was such an important hearing that I shall read into my report the recommendations of the Institute to the Commission.

1. The Institute of the Aeronautical Sciences recom-

mends that the Commission make definite recommendations regarding the necessity of maintaining engineering and research organizations in the aircraft industry. The most practical way to encourage the maintenance and development of such technical staffs is for all governmental agencies requiring aeronautical equipment and supplies to have a stated policy that they give preference to such organizations as have adequate engineering and technical personnel. This policy will provide an incentive to the aeronautical industry to employ a greater number of specialists in the various branches of the aeronautical sciences capable of conducting advanced development work. When all units of the aeronautical industry maintain adequate scientific personnel, a wider opportunity will be available for the consideration of new products and ideas.

2. The Institute recommends that the Army and Navy maintain sufficiently adequate staffs of aeronautical engineers to be supplemented each year with a definite quota of officers of those services who have been sent to our leading engineering schools for advanced work in the aeronautical sciences. We recommend that these staffs be used for the consideration of all technical problems of the Services, to prepare specifications, and to pass on engineering progress and products. We strongly recommend that the personnel of the Services do not engage in development work that can be undertaken by organizations in the aircraft industry; but, instead, look to the engineering staffs of the industry for this work.

3. We recommend that in each budget submitted by the Departments of the Government engaged in aeronautical work, the funds to be available for research and experimentation in the aeronautical sciences be specifically stated and that the amounts so appropriated be used for these purposes.

4. We recommend that greater emphasis be placed by governmental agencies on investigations in the fundamental applications of meterology, metallurgy, radio, chemistry, and physics to aeronautical development.

5. We recommend that the Government, through gifts of surplus material, and by utilizing their facilities and personnel in research, assist and encourage universities and technical schools which are engaged in aeronautical work.

6. We recommend that the National Advisory Committee for Aeronautics continue to be an independent governmental agency and that the work of fundamental research done by the Committee be supported by adequate appropriations.

Grover Loening, Elmer A. Sperry, Jr., Lester D. Gardner, and myself appeared personally before the Commission and elaborated on the above recommendations.

Pacific Coast Section. We have purposely avoided holding many meetings. Our membership is so widely scattered that we have felt that an Annual Meeting would be about all that we could expect a large number of members to attend. An event of outstanding importance was the organization of a Pacific Coast Section of the Institute and the holding of a very successful meeting at the California Institute of Technology. Through the interest and efforts of Dr. Clark B. Millikan and Donald W. Douglas, the dinner and meeting were great successes, nearly two hundred attending. There have been so many requests for the formation of sections that I feel sure that the example of those members on the Pacific Coast will be followed by others in geographical centers where we have a sufficient membership. If members wish to organize a section in their locality, they will be given every assistance.

Index Project. The Institute has been fortunate in having a project of indexing approved by the Emergency Relief Bureau of the City of New York. Mr. F. William Zelcer, Deputy Commissioner of the Department of Plants and Structures for Aviation, sponsored the project for his department. The Institute is indebted to him for his cooperation.

There have been many indexes of books and magazines and there have been digests of technical papers and bibliographies. But there is not available, so far as we know a simple and comprehensive index of photographs, drawings, maps, etc. Believing that a photograph usually is surrounded by descriptions, the Institute now has several specialists at work indexing the leading sources of material. When this index becomes sufficiently complete, it will be made available at the headquarters of the Institute, to members and others for reference. This index, we believe, will permit the Institute to render a service, not only to members, but to all who require information which is unavailable elsewhere.

Fellows. During the past year the authorized number of Fellows were elected by the Fellows themselves. We have not as yet elected any Foreign Fellow, excepting one foreign Honorary Fellow. Our reason for this has been that practically all of our foreign members are so distinguished that they are almost all worthy of the grade. It was thought that the best way of avoiding having to select the few for this grade was to elect none.

In the future, the By-Laws permit the election of ten American and ten Foreign Fellows each year. There are so many of our members who are not Fellows who are worthy of this grade that the organizers of the Institute, wishing to make the grade one of honor and high professional standing, limited the expansion of this grade, perhaps too severely. I am sure, however, that the membership will agree that it is better to go slowly rather than too fast in this respect. This year the Fellows will select ten members for this honor. The entire membership is invited to suggest to Fellows the names of members, who, in their opinion, are eligible, but may I suggest that this recommendation be accompanied with complete reasons and facts about the candidate.

Foreign Members. When the Institute was organized, the Council decided that it would be advantageous if distinguished aeronautical specialists living in many foreign countries were invited to become members.

About one hundred and fifty men who were specializing in the aeronautical sciences in other countries were invited to join. The Council decided to remit the dues of many foreign members in perpetuity.

After two years of experience, the advantages of such widespread membership have become apparent. When our members visit foreign countries they are given letters of introduction to our foreign members and these have been found to be helpful. Our foreign members are cooperating by sending papers to the Journal. But what is perhaps of greater importance is that the Institute is becoming more and more a place where foreign guests and members may be welcomed and given assistance when they visit the United States. Those of our members who have visited foreign aeronautical centers know the courtesy with which they have been received. Our members should know that a part of their contribution in maintaining the Institute is to provide a place which is comparable to similar centers in other countries. The letters of appreciation that have been received from those who have been assisted indicate that this service has been greatly appreciated. We were priviliged to give a dinner at which three of our distinguished British members were guests of honor.—T. O. M. Sopwith, R. C. Fairey, President of the Royal Aeronautical Society, and Lt. Col. J. T. C. Moore-Brabazon, member of Parliament and then President-elect of the Royal Aeronautical Society.

Finances. When the Treasurer presents his report, it will be noted that the amount received from members for dues was about one-sixth of the total amount of the cost of operating the Institute during its second year. The difference was made up by receipts from advertising, subscriptions from other than members, but principally from generous gifts from donors. Members will recall the generosity of Mr. Grover Loening in furnishing and equipping the Skyport and office. Other gifts have been acknowledged in the *Journal*, but last year the publishing costs of the *Journal* and administrative expense were far in excess of the income. To make up this difference, your officers invited donations from those who were interested in having the Institute broaden its activities. George J. Mead voluntarily started the subscription by giving One Thousand Dollars. Glenn L. Martin immediately donated similar amount. The Stanavo Specification Board added another thousand dollars. The Curtiss-Wright Corporation, The United Aircraft Corporation, and the Sperry Gyroscope Company all contributed one thousand dollars each to the fund. Mr. Sherman M. Fairchild gave Two Hundred and Fifty Dollars, and Mr. Charles H. Colvin, Fifty Dollars.

I am announcing these gifts in this report not only to express the appreciation of the Institute publicly, but to let our members know that the work of the Institute has been made possible by the generosity of interested friends. It is due to them that the Institute shows a balance on the right side of the ledger.

Fortunately, many of the expenditures made during our second year are non-recurring. When the Institute was started, the dues were made nominal. With the growth of our membership, the maintenance of a headquarters, and the publication of a *Journal*, a larger budget was required.

The Council believed that the members would be willing to pay a larger share than the original rate of dues would provide and, therefore, raised the dues and added an entrance fee. I am glad to say that seventy percent of our members have already paid their dues, which has, in effect, been a vote of approval of the action taken by the Council.

Another new source of revenue will be from advertising in the *Journal*. Already, enough has been secured to pay for the cost of printing the *Journal* this year and it is hoped that enough more will be received to engage an assistant to the Editor.

Administration. Perhaps the most difficult part of the work of the Institute comes under the classification of Administration.

It is hardly necessary for me to say much of the value of our Secretary's work. All of you have seen the Institute expand under his direction, and know the invaluable service that he has given at a time when it was most necessary.

The Advisory Board. The Council has not requested the Advisory Board to express an opinion on many questions. It has, however, afforded the Council, from time to time, a very useful method of securing a cross section of opinion of influential members of the Institute. As an instance, the Council asked for an expression of opinion regarding the increase in dues and acted only after a favorable response had been received from the majority of the Advisory Board. The Advisory Board has served a very useful purpose of broadening the official family of the Institute. In order for the Council to function, it has to have a quorum at its meetings. If its membership had a wide geographical distribution, this would be difficult, if not impossible, as was the case the first year. If members notice that most of the members of the council are from New York and vicinity, they should understand that it is due to the very strict laws of the State of New York under which the Institute is incorporated. It was to counteract the impression that too many Council members were from New York that the Advisory Board was created and the new rule regarding the election of officers from outside the Council membership was written into the By-Laws. To widen still further the directing group of the Institute, it will be proposed later, at this meeting, to increase the number of Vice-Presidents from two to five. This will enable the Institute to have as Vice-Presidents members from five sections of the country without endangering the securing of a quorum. When they can attend meetings, their opinions are accepted in the same spirit as those of voting members of the Council. I hope that the proposal will be approved.

In closing my report for the year, I wish to propose the establishment of a permanent endowment fund for the Institute. In this we are following the precedent of the Royal Aeronautical Society. It is raising a fund of $250,000 and already has received contributions of $50,000, the income of which goes to support the Society. Even with dues about twice those of the Institute, this fund has been found to be necessary to balance the budget.

If the suggestion meets with the approval of the new Council, there will be no general solicitation made from members. It is hoped that persons who are not members, but who are interested in the advancement of aeronautical sciences will wish to contribute by gift or bequest so that in a few years the Institute will be placed on a secure financial basis.

To my Fellow Officers, to the members of the Council, and the Advisory Board—to the membership at large, and to friends of the Institute, I express my sincerest appreciation for the cooperation they have given me during the past year.

CHARLES L. LAWRANCE

Major E. E. Aldrin, Treasurer of the Institute presented the Treasurer's report for the fiscal year ending September 30, 1934.

THE TREASURER'S REPORT

The Treasurer presents herewith the Annual Statement as of September 30, 1934, as required by the By-Laws.

In presenting this statement I wish to have it known that in accordance with a resolution of the Council, the auditor of the company with which I am associated made a very complete audit of the funds and accounts of the Institute from its incorporation and has certified to the correctness of the annual statement.

The outstanding figure of any balance sheet in these times is the one that may be red. I am glad to report that this figure of "our net unexpended income" was $4,170.64, and is shown in black. This compares with a similar figure last year of $1,176. 92. Of course, these amounts are not cash balances but our net worth in equipment, cash on hand, etc. The item of Accounts payable, as of September 30, 1934, of $3,546.54, has, I am glad to report, all been paid from the collection of practically all of the $3,693.40 Accounts Receivable.

The operating statement shows the greatest change from last year. Our receipts have increased from $3,572.00 last year to $19,223.04 this year, and this latter figure does not include anything for rent which was provided by a generous donor.

Our expenses increased in almost the same ratio, owing to the maintenance of the Skyport, a clerical staff, and the publication of the *Journal*. Last year we spent $15,757.41, of which $7,532.00 was for the *Journal*. It is of interest to note that the cost of the *Journal* was about $10 for every paying member.

As much of the expense last year was for equipment and practically all was donated, the budget this year will not have to include these expenditures.

I am glad to be able to report that the Institute has been ably managed financially by Major Gardner and if the members continue to pay their dues as they have in the past, the Institute can look to the future with confidence. While it is pleasant for a Treasurer to present such a satisfactory report, I wish to repeat what the President has already told you, that the Institute has been able to go through the second year with its program by the assistance of many donors. Your Treasurer hopes that members will cooperate with the new Treasurer so that so large outside assistance will not be required during the coming year.

I wish to support the proposal of the President that the Institute start an Endowment Fund. It may be many years before this will reach a sizeable amount but it is an essential requirement of all societies which have not, through the years of plenty, created surpluses on which they can draw when deficits occur.

E. E. ALDRIN

ANNUAL BALANCE SHEET
AS OF SEPTEMBER 30, 1934

Assets		
Cash in Bank and on hand		$ 1,242.22
Accounts Receivable		3,693.40
Office Furniture and Equipment	$3,476.95	
Less:		
Reserve for Depreciation	695.39	2,781.56
		$ 7,717.18
Liabilities and Capital		
Acccunts Payable		$ 3,546.54
Net Unexpended Income		
Balance September 30, 1933	$ 705.01	
Net Unexpended Income for year ended September 30, 1934	3,465.63	4,170.64
		$ 7,717.18

Operating Statement for the Year Ended September 30, 1934

Income		
Dues (less $2 per member for *Journal*)		$ 1,705.51
Initiation Fees		944.00
Donors:		
Cash	$4,505.00	
Office Furniture and Equipment	2,870.41	
		7,375.41
Meetings' Receipts	1,273.03	
Journal Advertising	1,580.00	
Journal Subscriptions (Members and others)	2,321.04	
		5,174.07
"Proceedings" Receipts	6.60	
Certificate of Membership Receipts	324.05	
		330.65
Accounts Receivable		3,693.40
		$19,223.04
Expenses		
Certificates of Membership	$ 279.62	
Collection and Exchange	4.14	
Electricity	48.47	
Meetings Expense	1,694.55	
Postage	502.58	
Printing and Stationery	523.56	
Telephone and Telegraph	239.85	
Miscellaneous Expense	333.55	
Journal—Printing, Promotion and Salaries	7,542.69	
Administrative—Clerical and Accounting Salaries	4,001.50	
Depreciation Expense $695.39		
Less:		
Office Furniture and Equipment included in inventory previously written off 108.49	586.90	15,757.41
Net Unexpended Income		$ 3,465.63

Major Lester D. Gardner read the Report of the Secretary.

The Secretary's Annual Report

Membership. The Membership Report as of January 1, 1935, is as follows:

Membership on January 1, 1934	655
Members elected during 1934	266
Resigned	11
Deceased	5
Total Membership on January 1, 1935	905

The division of the membership by classes is as follows:

	Foreign	American	Total
Honorary Fellows	1	2	3
Fellows	0	50	50
Scientific Members	85	114	199
Engineering Members	64	288	352
Technical Members	0	85	85
Pilot Members	4	65	69
Industrial Members	8	139	147
Total	162	743	905

To bring this report up to date there should be included about thirty applications which are pending and a few resignations. The remarkable feature of this growth in membership is that it has been a natural increase. There has been no organized effort made to secure new members. It may interest members to know that seventeen members pass on the qualifications of every applicant before an invitation is issued to the applicant to join.

There have been kindly suggestions made that possibly the Institute was expanding too fast and that it was undertaking too much for a society only two years old. When the Institute was organized, no one thought that its membership would grow so fast. One of the results of this growth of membership has been the necessity for increased activities. The Founder Members joined with the expectation of receiving little more than a membership list for their dues. When the membership reached about five hundred, the Council, at the request of many members, started the *Journal*. The cost of publication was found to be more than was received from dues. With a *Journal* and nine hundred members, the Institute had to have headquarters for its records and staff. While this was provided by generous donors at first, it is now an expense. In order to give the members what they wanted, it was necessary to increase the dues. It may interest our members to know that the present rate of dues of the Institute is only half those of the Royal Aeronautical Society and that it is necessary to charge over ten dollars a year for subscriptions to the Journal of the Royal Aeronautical Society. It is, therefore, evident that the increased activities have resulted from increased membership, and have required an increase in dues to provide these services. It is a cycle which is the inevitable consequence of success.

The Journal. The greatest problem of the Institute is the publication of the *Journal of the Aeronautical Sciences.* To start any publication without a fund to pay for the large amount of work required before the first issue appears, and to provide for the very high cost of printing a technical publication is a hazardous undertaking. The Council decided that the only way that the *Journal* could continue to be published was to ask support in the form of advertising. A few of the leading companies engaged in aeronautical activities have provided about half the amount necessary to carry on satisfactorily the work of publication. Each member of the Institute who wishes to have the *Journal* become an important source of valuable information can cooperate in nor more practical way than to urge the companies with which he is associated to contribute to the publication costs of the *Journal* by giving it advertising.

The work of the *Journal* divides itself into three parts. The editorial work has increased as it has been found to be less expensive to do it ourselves that to have others with less experience handle it. The Editor and the Editorial Board pass on the quality and acceptability of all papers. But it is the work of the Institute staff to urge those who have promised papers to submit them, to see that the papers passed on favorably by the Editor are prepared for publication, to return those which need further editing and those which are not acceptable. This work requires specialized editorial training and should be done by an editorial assistant. With a little more support from advertising, this will be possible.

The circulation of the *Journal* has, as is the case of all new publications, grown slowly. It now has about four hundred subscribers outside our membership. It should have much more and probably will have when it becomes better known. As the *Journal* is sent to all members for a part of their dues, it will be helpful if they will urge their associates to subscribe instead of borrowing a member's copy. In this way the revenue from subscriptions can be increased. As the *Journal* is a cooperative effort of members with no thought of profit, each member can feel that anything he can do to assist the *Journal* will bring him a better publication.

The third part of the work of the *Journal* is securing and handling the advertising. There has been no general solicitation except by letter. The mechanical handling of advertising requires most careful supervision.

Fortunately, the increase in issues from four to six a year does not involve a proportionately larger effort. With the revenue possible from six issues it is hoped that an adequate staff may be engaged.

The Skyport. Some members have indicated that they felt that those members who lived in the vicinity of New York had an advantage in the use of the attractive headquarters at Rockefeller Center. After over a year of observation, quite the contrary appears to be the case. Members in New York have their own offices and clubs and therefore do not require the facilities of the Skyport. Members from a distance as well as foreign visitors find the Skyport a place where they can bring friends to see the magnificent view and secure information. As our work enlarges, the Skyport, which at first was merely a club room, will have to be used more and more for executive purposes.

Index. There are many aeronautical indexes in existence. A committee of seven who have had wide experience in the

compilation and use of these indexes unanimously agreed that a most valuable addition to the already existing indexes would be one of pictures and biographies. As most pictures are accompanied by information, it was believed that such an index would provide a ready reference which would be more comprehensive and useful than any in existence. Of course, the cost of the work involved in such a compilation would be out of the question for the Institute. While the extent of the index cannot be predicted at this time, it is not improbable that a large staff of indexers from the Welfare Bureau may become available for an indefinite time. The work has been arranged so that it may be discontinued at any time and still be valuable. Should it continue for a year or more, it is certain that the Institute will have available one of the most important sources of information and reference to be found anywhere in the world. The Institute by supervising the work is providing employment to many specialists who would otherwise be out of work.

Library. While it is not possible at the Skyport to provide for a large reference library, the receipt of new books is becoming a source of added interest. Our magazine list through the exchange of our *Journal* is practically complete so that there is now on file all the leading aeronautical publications of the world.

Awards. The Reed Award has provided the Institute with an award which will greatly increase in prestige in the next few years. It is distinctive in that the recipient is selected by the Fellows of the Institute and not by a small committee. There are other prizes that should be available as a reward for other efforts. What is particularly needed is an award for young men engaged in the aeronautical sciences. A prize should be provided which could be given to a young man under thirty years of age who presents in a paper an exceptional advance which his investigations have uncovered. The Institute would have a reward for early work as well as for the more mature effort required for the Reed Award. The Institute does not wish to duplicate other splendid aeronautical trophies and medals. Your Secretary will be glad to discuss the many possibilities in this field with any member who is interested.

Publicity. The Institute has been fortunate in receiving the kind of publicity that increases its prestige. As its work in the presentation of advanced development in aeronautics continues, it will become more and more a center from which will radiate information to newspapers, magazines, and other publications.

The work accomplished by the Institute during the second year could not have been achieved except by the cooperative effort of all the officers. I have never known anyone to give so generously of his time to activities entirely outside of his busy professional life as your President. With all the other demands on his time, he served the Institute as Treasurer from its organization and until he became President last year. The Institute would probably have been little more than an organization on paper without his courage, foresight, and continuous effort. When the Institute was in serious financial difficulties he would cheerfully undertake, at a personal sacrifice of other pressing engagements, to search for a new donor. His irresistible good nature made him always successful. To him more than anyone else, the Institute owes its progress during its second year. Major Aldrin, too, has rendered invaluable services as Treasurer. It was due to Major Aldrin that the Skyport was made available to the Institute. He also helped your President in the securing of donors. Dr. Hunsaker has been engaged this year with the work of the Federal Aviation Commission, but he has never been too busy to give much of his time to the editorial work of the *Journal*. In the years to come, no one should have a higher place than these three founder members. To Dr. Millikan and Dr. Klemin the members should be grateful for the many hours they have given to the editorial work of the *Journal*.

The members of your Admissions Committee have passed on the qualifications of over three hundred members and graded them according to their best judgment. This was no perfunctory routine matter. Each member individually read the entire history of each candidate, considered his references and expressed an independent opinion on the grade to which he thought the applicant entitled. This has required hours and hours of work of a most tedious character. To this committee every member is indebted.

The Council has served the members well. It is really an Executive Committee which guides the Secretary by advice and establishes the policies of the Institute. The growth in membership and apparent success of our second year is due to the wise and careful direction of the Council.

Your Secretary wishes to express his appreciation to many other members who will have to remain nameless. He has never been refused a service and those he has asked have been innumerable.

If there have been shortcomings, mistakes or omissions it has been due to the fact that your Secretary has not been able, in the all too short days, to do more than look after the most pressing required work. The Institute is now an accomplished fact, its activities are becoming better organized, and its future appears to be assured. The American aeronautical sciences now have a representative organization which will increase in importance in the years to come. If members will cooperate as they have during our first two years, I am sure that the Institute will continue to be successful.

LESTER D. GARDNER

After the reading of the reports of the President, the Treasurer and the Secretary, the President asked for a discussion. The members voted to approve the three reports.

Messrs. Loening, Klemin and Wilford were appointed Tellers to report on the proxies which had been received for the meeting. They reported that 144 proxies had been received in good order. Of these, 127 members had voted in favor of the amendment to the Constitution increasing the number of Vice-Presidents from two to five; five members were opposed and 12 did not vote.

The President informed the meeting that a

notice had been sent to all members as required by the Constitution on amending that part of Section 1 of Article III of the Constitution of the Institute of the Aeronautical Sciences, Inc., which heretofore read "The Council shall elect the President, two Vice-Presidents and the Treasurer of the Institute" to read: "The Council shall elect the President, five Vice-Presidents and the Treasurer of the Institute."

The one hundred members present and the favorable votes by proxies voted to amend the Constitution as read.

The Nominating Committee reported the following nominations:

For the Council for three years ending 1938; Charles H. Chatfield, Sherman N. Fairchild, C. H. Colvin and Luis de Florez.

For the Advisory Board; Jack Frye, E. A. Stalker, G. M. Bellanca, Th. von Kármán, H. L. Dryden, J. H. Doolittle, C. L. Egtvedt, W. R. Gregg, E. T. Allen, J. H. Kindelberger, Alexander Klemin, I. Machlin Laddon, Glenn L. Martin, John K. Northrop, A. A. Priester, H. J. E. Reid, Albert F. Hegenberger, Garland Fulton, Gerard Vultee, Leroy R. Grumman.

The meeting voted to elect to the Council and Advisory Board the names presented by the Nominating Committee.

The President called for nominations for the Nominating Committee for the ensuing year. The following members were nominated and elected.

Glenn L. Martin, H. C. Richardson, Ralph Upson, Alexander Klemin, and George W. Lewis.

The President called attention to the reference he had made in his Annual Report to the creation of the "Sylvanus Albert Reed Award." The meeting gave a rising vote of thanks to Dr. Reed for his generosity in establishing this award.

The President informed the members that the Institute was greatly indebted to Columbia University and to Professor George B. Pegram for the privilege of holding the Annual Meeting and Annual Dinner of the Institute at the Physics Building and the Faculty Club.

A vote of thanks was unanimously given to Columbia University and Professor Pegram, and the Secretary was directed to write a letter of appreciation to Dr. Nicholas Murray Butler, President of Columbia University.

The President called for a recess for five minutes so that the new Council could meet and elect officers for the ensuing year. Upon reconvening, the Secretary announced the results of the election.

President—Donald W. Douglas
Vice-Presidents—Clark B. Millikan, L. C. Milburn, G. W. Lewis, E. E. Wilson, T. P. Wright
Treasurer—E. E. Aldrin
Secretary—Lester D. Gardner

The President announced that Dr. Joseph S. Ames, President of Johns Hopkins University, and Chairman of the National Advisory Committee for Aeronautics, had been elected an Honorary Fellow "*For his able direction of aeronautical research along lines of effort that have advanced aeronautical science with resulting benefit to our national defense and commercial aeronautics.*"

The President expressed the appreciation of the members to Dr. Ames for his advice and helpfulness while serving as a member of the Council of the Institute since the Institute was founded.

The meeting voted to express the appreciation of the membership to the officers for their excellent conduct of the Institute during the past year. President Lawrance thanked the membership on behalf of the officers for this evidence of confidence. The meeting then adjourned.

Letter to the Editor

In the January issue of the Journal of the Aeronautical Sciences, Professor R. H. Smith reviewed, in about one thousand words, the 250,000 word content of the first volume of "Aerodynamic Theory," edited by W. F. Durand. Based on this ratio, only four words should be allowed for a review of the review. I apologize for claiming more of the valuable space of your Journal for this purpose, hoping that my remarks, if shared by a sufficient number of readers, may possibly have an influence on the future policy of the Journal concerning reviews of literary events and new scientific books.

I wish to emphasize quite definitely that my objection to the review in question is not based on the fact that the reviewer comments unfavorably on certain aspects of the book. I believe that the personality, the reputation, and the prominence of an editor or author should not interfere with an objective and severe criticism of the shortcomings of his work.

Neither do I wish to blame the reviewer for not having found some words of appreciation for the fact that the six volumes of "Aerodynamic Theory," in spite of probable shortcomings, represent the first attempt in the history of aerodynamics to present the state of this science in a work of encyclopedic character. Most reviewers would be inclined to mention the indefatigable energy and the broad vision of the editor in carrying the work to a conclusion. However, I repeat, I will not criticize the reviewer for lacking this appreciation. After all, everybody is entitled to see historical, scientific, and literary events from as restricted a point of view as seems enjoyable or practical to him. The reviewer is at least consistent in this point: apparently he finds it a sufficient acknowledgment of Giacomelli's historical sketch, which itself represents a literary event in the history of aerodynamic science, to state that "it is very creditably done."

My objection is that the review does not give to the reader of the Journal what he is entitled to expect: clear and concise information about the contents and the merit of the book reviewed, and about its place in the body of scientific literature. I do not believe that a reader who has not yet read the book reviewed really knows much about it after reading the review. I myself am familiar with the work and have read the review over several times, but I must confess that I often found more difficulty in understanding what the reviewer meant than in following any of the mathematical deductions in the first volume of the "Aerodynamic Theory."

The review first states correctly the main purpose of the volume in question. After this short introduction, one would expect a discussion of the contents of the various chapters. Instead, however, the reader is entertained with some philosophical remarks of a general character which are so misleading that I believe they need some short comment: The reviewer says that, "as is usually the case with the first volumes of a series such as this, two quite different appraisals are possible":

(1) On the basis of the material which it covers;

(2) On the basis of its adequacy as a reader's aid for the whole series.

He finds the book quite satisfactory from the first point of view because of the fact that the material which it covers has already been well done for the most part and is easily available in familiar volumes, so that it could hardly be presented in other than a satisfactory manner. If this explanation is true, it is hard to see why new text and reference books on classical subjects are ever written and to explain why some books on classical subjects are so excellent and others so poor. The reviewer concedes a certain elegance in the presentation, saying that this elegance is characteristic of third and fourth generation treatments. This statement shows a certain lack of familiarity with the work of the great classical writers in mathematics and mechanics, who are generally considered as models not only for the ingenuity of their ideas, but also for the elegance of their presentation. In this connection, it would be interesting to inquire how the reviewer finds three or four generations between the initiators of some of the theories treated and the author of the chapters in question.

The main objection of the reviewer under (1) is a certain "tendency to over-emphasize manipulations." I cannot consider this as a valid criticism, since the outspoken aim of the volume is to help the reader of the subsequent volumes through such formal operations as are generally not given in engineering textbooks and curricula but which are sometimes unavoidable in aerodynamic theories.

The reviewer's chief objection under (2) is that it is likely that, after all the volumes are finished, the mathematical aids will be found incomplete and inadequate. This criticism reminds me somewhat of the story of the wise girl who was found by her mother sitting on the staircase to the basement, weeping bitterly. Asked by her parent about the cause of her grief, she said, "Last night I was in the basement with my sweetheart, and we found that one stone in the wall was loose. Now I will marry him next Christmas, and the following year we shall have a baby, and then the baby will grow up, and then the child will surely go one day into the basement, and then the stone will fall down and kill my child. What shall I do? I cannot possibly marry."

I hope that many students of aerodynamic science agree with me that it was very fortunate that Dr. Durand did not follow this logic but courageously carried out the preparation of the mathematical aids.

TH. VON KÁRMÁN

California Institute of Technology,
February 10, 1935.

An Appreciation

During the past seven months of service of the Editor on the Federal Aviation Commission, members have been indebted to Dr. Alexander Klemin and Dr. Clark B. Millikan for the editorial direction of the Journal of the Aeronautical Sciences.

J. C. HUNSAKER

Institute Notes

Charles Healy Day and Paul G. Zimmerman are now in China in charge of aircraft construction for the Chinese government. Mr. Day is at Canton and Mr. Zimmerman is near Hangchow. In a recent letter Mr. Day writes:

"The Air Force here is surprisingly modern. I have seen more than sixty airplanes flown by Chinese pilots in the air at one time. I have also seen 54 military planes flying in formation with as good a performance as one would expect to see in any country. Most of the planes here are American and American products are greatly favored."

Flight Lt. F. W. Haig, a member of the Institute living in Melbourne Australia, sent the following thoughtful cable to the members attending the Third Annual Meeting.

"Greetings and best wishes for a successful Institute meeting."

Dr. E. B. Wolff, Director of the Ryks Studiedienst Voor de Luchtvaart at Amsterdam, Holland, a Scientific Member of the Institute, visited the Skyport in January. He was accompanied by J. van der Heijden, Inspector of Aircraft for Holland.

Squadron Leader D. C. MacKenzie Hume of the Royal Canadian Air Force and member of the Institute visited the Skyport in January.

Necrology

Dr. Hugo Junkers, an Engineering Member of the Institute, died on February 3d at Munich, Germany, on his 76th birthday.

Dr. Junkers, one of the foremost German inventors and scientists, left an academic post as Professor of Thermodynamics to develop at the Junkers works at Dessau a varied line of heaters, marine and airplane engines, calorimeters, and other applications of thermodynamics. The designs of Dr. Junkers were marked by originality of conception and radical departures from current practice. He is credited with the metal low-wing monoplane, corrugated-skin wing construction, the thick wing of high efficiency, and the opposed piston airplane diesel engine.

After the war the Junkers company operated air lines in many countries. In Germany the Junkers air lines became a part of the present Deutsche Luft Hansa network. Last month, the Institute received a courteous reply to a Christmas Greeting in which Dr. Junkers stated that he hoped that the year 1935 would be a most successful one for the Institute.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have their requirements listed without charge.

Wanted:

Graduate Engineer and a high type business executive who can fit into foreign and domestic aircraft sales together with administration of business, and other assignments from the President of the Company. Write Box 22, Institute of the Aeronautical Sciences.

Aeronautical Engineer who can write technical articles with some degree of human interest. Write Box 23, Institute of the Aeronautical Sciences.

Good stress analyst for temporary position. Write Box 24, Institute of the Aeronautical Sciences.

Available:

Young man, age 26, B.S. in M.E., M.S. (Aeronautics); Specialist in rotating wing aircraft. Write Box 25, Institute of the Aeronautical Sciences.

Aircraft engineer and designer. Eighteen years experience. Specialist in application of Aerodynamics to design. Designer of some of the most successful American high-speed racing and military aircraft. Write Box 26, Institute of the Aeronautical Sciences.